A CHARACTERIZATION AND ANALYSIS OF THE FLOOR PLASTERS FROM THE ACROPOLIS AT COPAN, HONDURAS

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ABSTRACT

A program of plaster analysis was instituted by the Early Classic Acropolis Program as part of a larger study focused on the construction methods and materials used by the Maya. Representative samples of floor plasters from the Copan Acropolis, the center of the site's architectural development during the Classic period (ca. AD 420-800), were submitted to the Architectural Conservation Laboratory (ACL) of the University of Pennsylvania's Historic Preservation Graduate Program for analysis. A laboratory research program was to designed to investigate the structure and composition of the plasters comprised of a hierarchical series of analysis, including archival research, optical microscopy, thin section petrography, scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS), and X-ray diffraction (XRD).

The identification of plaster constituents, their physical characteristics and proportions were the most important parameters of a discernible pattern in production modes and materials selection. The majority of plaster samples were composed of a lime matrix and various aggregates, such as those derived from limestone, volcanic tuff, and silica sand. Obtaining binder to aggregate ratios was difficult by the conventional mortar analysis techniques used in the study since the matrix and partial aggregrate fraction both were calcareous materials.

Aggregate particle sizes, shapes and proportions changed over time but without a distinguishable evolution. One exception was a reduction in the amount of carbon visible in the plasters from the last construction phase, suggesting a change in either production techniques or materials available for lime production. Overall, the plasters appeared to

have a compact lime matrix devoid of cracks, and included a well balanced distribution of particles to indicate the Maya had an empirical knowledge of the critical properties required for durable plasters.

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INTRODUCTION

> *The city was desolate....It lay before us like a shattered bark in the midst of the ocean, her masts gone, her name effaced, her crew perished, and none to tell whence she came, to whom she belonged, how long on her voyage, or what caused her destruction - her lost people to be traced only by some fancied resemblance in the construction of the vessel, and perhaps, never to be known at all. The place where we were sitting, was it a citadel from which an unknown people had sounded the trumpet of war? or a temple for the worship of the God of peace? Or did the inhabitants worship idols made with their own hands and offer sacrifices on the stones before them? All was mystery, dark, impenetrable mystery..here an immense forest shrouds the ruins, hiding them from sight, heightening the impression and more effect, and giving an intensity and almost wildness to the interest.*[1]

For four centuries Copan, set resplendently in its valley in western Honduras, was the capital of a dominant polity, extending its power throughout the southeast Maya region. The earliest traces of human occupation date to the middle Pre-Classic era (ca. B.C. 1000), when its inhabitants began to adapt to communal living. By the Classic period (A.D. 420 - 820) it had manifested the characteristics of a complex state organization and grew in grandeur and prosperity to which its monumental architecture and elaborately carved stelae are testament. There was no moment of completion, for with every subsequent ruler came a more formidable building designed to legitimize his authority. By the end of the Terminal Classic period (ca. A.D. 822)--for reasons not entirely resolved--Copan, like other lowland Classic centers, suffered a protracted decline. Construction of administration, residential, and ceremonial buildings ceased. Copan was abandoned and faded into obscurity.

Little human activity disturbed the site until its discovery in 1576 by the Spaniard, Don Diego de Palacios. In 1841, it was brought to public attention by the writer, John

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[1]John Lloyd Stephens, *Incidents of Travel in Central America*, New York: Harper, 1841: 105.

Lloyd Stephens, and artist, Frederick Catherwood, in *Incidents of Travels through Central America,* rekindling interest in this civilization which had demonstrated by its material remains a sophisticated artistic ability and complex religious beliefs.

Over a century of excavation, research and restoration programs have been undertaken, making Copan one of the most thoroughly investigated Lowland Maya sites. Institutions such as the Peabody Museum of Harvard University, the Carnegie Institute of Washington, the University of Pennsylvania, and a host of renowned Maya scholars have been charged with excavating and interpreting the site and its environs.

In 1988, the Early Copan Acropolis Program, directed by Dr. Robert Sharer, under the auspices of the Honduran Institute of Anthropology and History (IHAH), with the Proyecto Arqueológico Acrópolis Copán (PAAC), was instituted to investigate the Acropolis, an architectural complex used by Copan's ruling dynasty from ca. A.D. 420-820.

A program of plaster analysis and characterization was initiated in 1995 as part of a larger study focused on the construction methods and materials used by the ancient Maya of Copan during the establishment of power structures. Representative samples of floor plasters were retrieved from various locations in the Acropolis from the ECAP's Operation 1 and Arqueológico Agurcia's Operation 41 and submitted for analysis to the Architectural Conservation Laboratory (ACL) of the University of Pennsylvania's Graduate Program in Historic Preservation.

This represents the methods and findings of an experimental laboratory program designed to characterize the floor plasters of Copan. Characterization of samples involved archival research, light microscopy, X-ray diffraction analysis (XRD), and scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS). General questions posited from characterization and analysis included:

1.) What are the plaster constituents and their relative proportions?

2.) Are there compositional changes in materials and technology over time?

3.) What properties would their materials have displayed?

The investigation of Maya plasters aims to further the archaeologists' goal of illuminating the life of the Maya as a whole by exposing identifiable traits in production modes and materials selection which are a reflection of their knowledge, practice, and experience. As Abrams submits, "state level political power is reflected in expanded scales and quality of elite architecture and that such architecture required increased capacity to produce lime plaster.[2]

To establish a context for the investigation, Chapter One begins with a review of the ancient Maya world, their territory, history, architectural tradition, and the region of Copan. The second chapter includes a discussion of plaster as an architectural element and a review of previous Maya plaster studies. Chapter Three follows with a description of the layout and chronology of the Copan Acropolis, including archaeological campaigns. Chapter Four describes the metholdology used, the procedures and the results of the investigation. Finally, Chapter Five, "Conclusions and Recommendations," offers an assessment of data and presents recommendations for further study.

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[2] Eliot Abrams, "The Evolution of Plaster Production and the Growth of the Copan Maya State," in *Arqueologia Mesoamericana: Homenaje a Wiliam T. Sanders*, Guadalupe Mastache, Jeffrey Parsons, Robert Santley, Carmen Serra Poche, INAH, 1996: 193.

CHAPTER ONE
COPAN AND THE ANCIENT MAYA

1.1 THE ANCIENT MAYA

1.1.1 TERRITORY

Prehistoric evidence indicates the Maya were of Asiatic origin who migrated to Mesoamerica by way of the Bering Strait over 12,000 years ago. Their settlements centered on the Yucatan Peninsula, extending into Mexico and eastern Belize in the west to the Guatemala highlands and the eastern edges of Honduras and El Salvador. In addition to Copan, other large important Maya sites include Tikal, Nakbe, El Mirador, Uxmal, and Chichen Itza (Figure 1).

The Maya territory contains one of the world's most diversified environments, which is typically divided into two regional zones: the northern lowlands and southern highlands. Although the earliest Maya centers were located in the northern region, it is the south which presently contains the greatest population concentration of the entire Maya area.

The northern lowlands are generally characterized by hot tropical conditions, with variations in elevation (below 800 meters), rainfall, drainage, and soils though not as distinct as those in the highland regions. Different types of vegetation thrive in the lowlands, particularly those indigenous to tropical rainforests. Various trees, such as mahogany, ceiba (sacred to the Maya), cedar, rubber, allspice, avocado and palm to name a few, are abundant primarily in the southern lowland region. In addition to vegetation,

Figure 1. Map of the Maya area, showing archaeological sites. From Robert Sharer, *The Ancient Maya*, (Palo Alto: Stanford University Press, 1994), 24.

the forests and rivers support a wide variety of animal life, including a multitude of reptiles, game, primates, birds and fish which provided sustenance for the ancient Maya.[3]

The highlands are situated 800 meters above sea level, and while the environment is more dramatically diverse than the lowlands due to a varied topography, it is a temperate region. The area is roughly subdivided by its geological manifestations: the south, dominated by recent volcanic deposits, and the north which is characterized by older metamorphic formations.

As a consequence of its denser population, particularly in the southern region, several highland areas have suffered a reduction in vegetation and animal life. Previous studies indicate the original flora consisted of an evergreen and deciduous forest. Today predominantly pine and some cypress or juniper prevail at higher elevations. Several animal species similar to those in the lowlands can still be found. In the northern region lives the rare quetzal bird, venerated by the ancient Maya for its magnificent plumage which ornamented the headdresses of the ruling elite.

1.1.2 ANCIENT MAYA CHRONOLOGY

Ancient Maya culture evolved over several thousand years, through distinct stages.[4] Originating in the Lithic period, ca. B.C. 12,000, migratory bands roamed throughout the New World, depending on a wide range of locally available foodstuffs and stone chipped tools. As their reliance on agriculture progressed, various plants and animals were domesticated and more permanent dwellings constructed.

During the Archaic period, B.C. 6,000 - 2,000, the sea provided year-round sustenance for the population, as evidenced by the communities found along the Caribbean and Pacific seacoasts. Agriculture had become firmly established in this region, prompting

[3] Robert Sharer, *The Ancient Maya*, Palo Alto: Stanford University Press, Fifth Edition, 1994: 30-33.
[4] Ibid: 557.

the inhabitants to construct the first known villages which set the foundation for the New World.

The Pre-Classic period, B.C. 2,000 - A.D. 250, is marked by the development of a more complex society, characterized by social stratification, religious and economic institutions, and hereditary leadership. Shelter construction began to make the transition from perishable materials, such as wattle and daub faced with mud plaster, to more elaborate masonry structures. Pollen studies indicate agriculture centered on the cultivation of maize, beans, and squash which continued beyond the Classic period.

The Maya reached their apogee during the Classic period, A.D. 250 - 900, when several cultural groups expanded in Mesoamerica and further south into Central America. Their cities were characterized by full time craft specialization, greater social stratification (classes), complex religious beliefs, and the employment of armies and guards to protect central authority.

As their refinement of agriculture and architecture progressed to forms more appropriate to their lifestyle and environment, the Maya were free to pursue artistic and intellectual activities. Corollary technologies began to take on a new importance, manifested by a unique style of art, sculpture and pottery, hieroglyphic writing, calendrical system, and a knowledge of mathematics and astronomy considered to be the most highly developed in the New World.

Overlapping with the Post-Classic era is a period known as the Terminal Classic, A.D. 900 - 1500, when northern cities in the Yucatan Peninsula witnessed the development of powerful states, including a considerably larger and more complex military structure prior to European colonization. In the southern region however, many cities were apparently abandoned as evidenced by a sudden cessation of construction and artistic activity associated with the elite classes.

1.1.3 MAYA ARCHITECTURE

" the ruins and vestiges of a great civilization and of superb edifices, of such skill and splendor that it appears that they could never have been built by the natives of that province."

Diego Garcia de Palacio to King Philip II, 1576

The architectural vestiges of the Maya elite are among the most tangible evidence of the beliefs, traditions, and complexities, as well as the advanced level of achievement attained by this New World civilization. While Maya architecture evolved over the centuries, exhibiting stylistic variations throughout its vast territory, a distinct architectural language persisted. Elaborately decorated temples and pyramids towering above expansive plazas studded with monumental sculptures were constructed to engender an awe-inspiring effect over the surrounding inhabitants. It was in part a manifestion of Maya ideology, as all Mesoamerican art and architecture were imbued with religious symbolism, and an attempt by rulers who sought to perpetuate their supernatural authority by creating a "space of power, both sacred and secular; a meeting place of the real and the supernatural."[5] (Figure 2)

In creating an environment which was to reflect their world-view, site location and building orientation warranted considerable planning . Ceremonial centers were established near caves, rocks, mountains, and "special topographical features" to enhance otherworldly associations.[6] Otherwise, the terrain was modified to accomodate established architectural forms. In the flood plains of Copan for example, mounds were constructed, whereas, in contrast a more mountainous region may have called for a

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[5] Elizabeth Benson, "Architecture as Metaphor," In *The Fifth Palenque Round Table, 1983, Volume 7,* Merle G. Robertson, Editor, San Francisco: Pre Columbian Art Research Institute, 1985, p. 188.
[6] John Carlson, "A Geomantic Model for the Interpretation of Mesoamerican Sites: An Essay in Cross-Cultural Comparison," in *Mesoamerican Sites and World-Views,* Edited by Elizbeth Benson, Washington, D.C.: Dumbarton Oaks Research Library, 1976: 163.

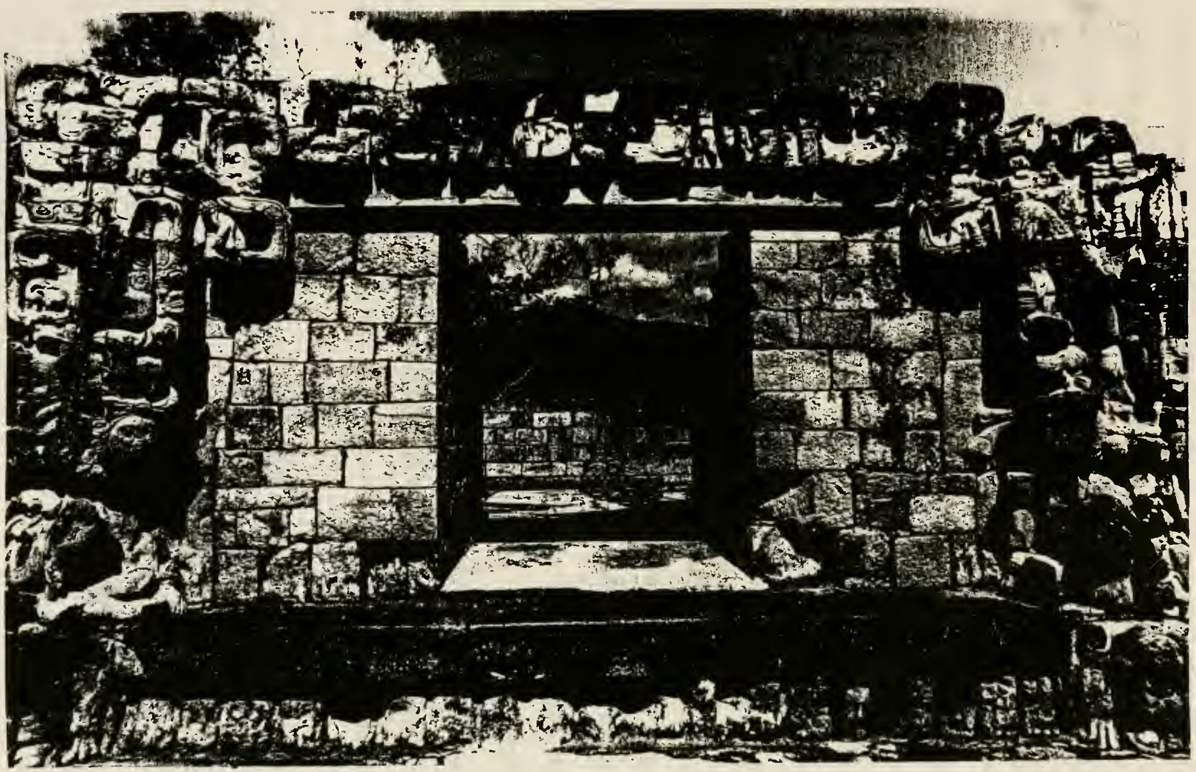

Figure 2. Doorway of Temple 22, Copan. From Giuseppe Orefici , *I Maya di Copan*, (Milan: Skira, 1997), 19.

levelling of natural elevations.[7] Hallmarks of Mesoamerican centers include principal structures oriented along a designated axis, ball courts, terraces and elevated platforms arranged to form plazas, and stelae (stone monuments) punctuating a main axis. It has been suggested that at Copan, buildings were oriented assymetrically in the belief it would bring about good fortune.[8]

Settlement work indicates that Maya centers thrived with several classes of people, trade, markets, and crafts in addition to providing the ruling caste a focus for theological and scientific discourse, religious rituals.[9] Bishop Diego de Landa, an early chronicler of the Maya, described their architectural centers as consisting of a hierarchical distribution of buildings, with religious structures at the core, surrounded by residences of the lords and priests, followed by the houses of important society members, and finally the dwellings of the lower classes which were scattered throughout the countryside.[10]

Despite regional variations, each building type served specific functions. Prinicipal structures classified within ceremonial centers include buildings, such as palaces and temples; substructures (an extensive elevated area consisting of masonry walls containing a rubble fill, supporting a building), such as terraces, platforms, and truncated pyramids; and platforms (an extensive elevated area, an intermediate construction, supporting one or more substructures and buildings).[11] Since almost all buildings stood on elevated surfaces, stairways were the usual provision for access to the superstructure.

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[7] William Fash and Robert Sharer, "Sociopolitical Developments and Methodological Issues at Copan, Honduras," *Latin American Antiquity*, Volume 2 (2), 1991: 178.
[8] John Carlson, Ibid: 164.
[9] Christine Carelli points out that Maya cities were originally though to be empty ceremonial centers as Tatiana Proskouriakoff states in *An Album of Maya Architecture*, Norman: University of Oklahoma Press, 1963: xiv. However, further settlement work indicates otherwise; Christine Carelli, personal correspondence, November 1998.
[10] Alfred Tozzer, *Landa's Relacion de las Cosas de Yucatan*, Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University, Vol. 18, Cambridge, MA, 1941: 62-64.
[11] Robert Sharer, et al. "Early Classic Royal Power in Copan: The Origins and Development of the Acropolis (ca AD 250-650), by Robert Sharer et al, School of American Research Advanced Seminar: *Copan: The Rise and Fall of A Classic Maya Kingdon, October 10-15, 1994., Philadelphia: University of Pennsylvania Museum*, Philadelphia, 1994: 2.

Stairways not only served as procession routes to temples but as seating for spectators. Some stairways, such as the Hieroglyphic Stairway at Copan, were major architectural constructions in their own right.

Buildings were commonly modified, expanded, or razed when they had outlived their usefulness. In the latter case, the Maya brought in large quantities of fill to bury the entire area. They capped this with a new plaster floor to serve as a foundation for subsequent structures. Over time, a massive agglomeration of superimposed buildings developed sufficient height to be called an acropolis. Both the construction and destruction of buildings assumed ideological implications, such as symbolizing the ritually celebrated life cycle.[12] On a more practical level, it was the most efficient and economical means of accumulating greater height and mass.

Unlike many ancient cultures, Maya architecture was not predominantly megalithic. Instead, most structures consisted of coarsed ashlar masonry supporting a rubble fill of pounded earth or clay and mixed with broken stone.[13] The purpose of this technique, similar to Roman wall construction, was to increase the height and mass of a wall.[14] Stone masonry consisted of either rectangular blocks of a uniform size, ranging from 12 to 35 cm, like those at Copan, or blocks with the inner part tenoned to set into mortar fill. Consequently, ornamental stones did not have to conform to any structural requirements, thereby allowing a greater freedom in their elaboration.[15]

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[12] Sharer, Ibid: 3. E.H. Thompson suggested that the continual expansion and reinforcement of buildings may indicate yearly renewal rites; Edward Thompson, "*People of the Serpent*," Boston: Houghton Mifflin Co., 1932: 99. Aubrey Trik observed as many as 25 layers of stucco on façade sculpture; Aubrey Trik, "Temple XXII at Copan, in *Contributions to American Anthropology and History*, Volume V, Publication 509, Washington, D.C., Carnegie Institute of Washington, 1939: 96.

[13] Spinden suggests this type of construction was an extension of the original earthen wall construction. However, some early structures exhibit stones which were integral to the load bearing structure; Herbert Spinden, *The Art of the Maya*,, PMAE Memoirs 6, 1913: 108.

[14] As a consequence, excessively thick walls gave the impression of massive buildings, while the interior spaces were considerably smaller.

[15] Spinden, Ibid: 109.

Limestone, ubiquitous throughout most of the Maya region, was the principal source of construction material.[16] Likewise, the manufacture and use of lime played an important role in Maya architecture for achieving various structural forms and ornamentation. At first, lime based materials were most commonly used in a sparing fashion as a mortar and a monolithic coating for buildings. Later, they evolved into serving both a structural capacity such as floors, or as three-dimensional modeled decorations (stucco reliefs) to adorn walls, stairways, platforms, and roofcombs.[17] This would imply the development of Maya architecture corresponded with improvements in the manufacture of lime.[18] The copious amounts of plaster consumed for construction is all the more remarkable considering the Maya did not work with metal tools for procuring wood and quarrying stone.

Architectural decoration in the central Maya region generally evolved from that executed in stucco relief, to the elaborately carved stone adorning facades.[19] Copan is particularly noteworthy for the beauty and depth of its Late Classic stone sculpture which is partly attributable to the use of volcanic tuff, a harder and more durable stone than the limestone found at most Lowland Maya sites.[20] While exteriors were elaborately embellished, interior decoration concentrated primarily around doorways and sills. Ornamentation was almost exclusively confined to the upper zones of facades and manifested in realistic figures or geometric-patterned mosaics.

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[16] In areas such as Copan and Quirigua characterized by a relative paucity of limestone, structures were built of the more readity available tuff and sandstone, respectively. Additionally, whereas masonry was generally set in lime mortar, Copan and Quirigua masons utilized mud as a binding material and relied on the weight of the stones for support.

[17] The central Maya region employed stucco for architectural decoration, whereas at Copan originated the elaborately carved stone sculptures to adorn facades. This characteristic was later adopted in the northern Lowlands, known as the Late Classic Puuc style; Robert Sharer et al., *The Ancient Maya*, Ibid.: 631.

[18] Proskouriadoff, Ibid: xv.

[19] Sharer, *The Ancient Maya*, Ibid: 631.

[20] Christ Carelli, personal correspondence, November 1998.

For decorative purposes, as well as an expression of iconographic and symbolic meanings, building surfaces were highlighted or painted in their entirety.[21] Color had the ability not only to enliven forms but, depending on the context of the building or sculpture to that culture, to convey meaning related to cardinal directions, lineage, and sacredness.[22] Monochrome red (iron oxide) had the widest distribution among Maya sites both for economic reasons, as mineral and clay sources were abundant and easy to process, and its associations with the east, the preeminent cardinal direction; the blood complex, legitimizing political succession; and the home of the principal Rain God, Chac.[23] In contrast to white, red significantly reduced the sun's glare, and in some instances was applied on exterior plaza floors. While red was the most common, other colors such as yellow and green (iron oxide), "Maya Blue" (indigo-attalpulgite clay), black (carbon black), white (calcium carbonate) were also used, albeit to a lesser extent during the Classic period. As suggested by Kowalski, these "strong colors endowed figures, masks and other sculptural motifs with a more profound existence, and increased their potency as emblems of supernatural legitimacy and dynastic dominion."[24]

1.2 COPAN, HONDURAS

[21] The several paint layers found in Temple 22 at Copan suggest frequent repainting and may indicate the occurence of ritual activities;
Linda Schele, "Color on Classic Architecture and Monumental Sculpture of Southern Maya Lowlands," in *Painted Architecture and Polychrome. Monumental Sculpture in Mesoamerica, A Symposium at Dumbarton Oaks, October 10-11, 1981*, Edited by Elizabeth Hill Boone, Washington, D.C.: Dumbarton Oaks Research Library, 1981: 31.
[22] Elizabeth Hill Boone, "The Color of Mesoamerican Architecture and Sculpture," Ibid: 175.
[23] Boone, Ibid: 182. Copan, Tikal, and Seibal were observed to use red (hematite, Fe_2O_3) exclusively on their sculptures and monuments, with the exception of Mound A at Copan (CV-43), excavated by Levanthal, Willey, and Fash which was found to contain rooms painted in directional colors: the east room colored red, the west room, black, the color of night and the center room, green, representing the center of the world; Gordon Willey et al., "Maya Settlement in the Copan Valley," *Archaeology* 31 (4), 1978: 40. According to Sharer, the rain diety, Chac, had four principal aspects, each linked to cardinal directions: red symbolized the east; white, the north; black, the west; and yellow, the south; Sharer, Ibid: 531.
[24] Jeff Karl Kowalski, "Painted Architecture in the Northern Maya Area," In *The Color of Mesoamerican Architecture and Sculpture*. Ibid: 82.

1.2.1 THE ENVIRONMENT

Copan is situated in the southeastern section of the Maya region in Honduras, approximately twelve miles from the border of Guatemala. Surrounded by steeply sloped mountains at an average elevation of 700 meters, it is unique in geological and climatic conditions among the surrounding lowland areas. In contrast to the prevailing tropical environment of the south, Copan is characterized by marked seasonal changes as well as a highly varied landmass, comprised of mountains, foothills, floodplains, and river terraces.[25] The mean annual temperature is 78°F, which is atypically mild for this area. While there are some tropical rain forest attributes, such as jungle-like tree patches, the Copan Valley gives the impression of a somewhat semi-arid environment, especially during the dry season (January - May). The rainy season (June - December) brings periods of steady precipitation, averaging 2,000 - 3,000 mm annually. (Figure 3)

The most significant environmental feature is the Copan River which flows westwardly through the Copan Valley, feeding into the northward-flowing Motagua River in Guatemala, and into to the Carribbean Sea. Unlike the Yucatan Peninsula where surface water is relatively scarce, the river was a constant source of water, cobble stones, and deep alluvial soils which were exploited for construction.[26] The proximity to the river was undoubtedly an alluring feature to settlers who had occupied the area by ca. B.C. 1000.[27] Geomorphological studies indicate that until about the eighth century A.D., the annual flooding of the valley bottom renewed the fertile and well drained soils, making it ideal for a people reliant on agriculture.

The surrounding mountains and foothills provided natural resources such as volcanic tuff and limestone which were used for the construction of buildings and

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[25] William L. Fash, *Scribes, Warriors, and Kings,* New York: Thames and Hudson, 1991: 27.
[26] Eliot Abrams, *How the Maya Built their World*, Austin: University of Texas Press, 1994: 16.
[27] William Fash and Robert Sharer, "Sociopolitical Developments and Methodological Issues at Copan, Honduras," Ibid: 178.

Figure 3. Copan Environs. From Giuseppe Orefici, I Maya di Copan (Milan: Skira, 1997), 73.

sculpture. Tuff is abundant throughout the mountainous region and used for the construction of every masonry structure and stela. Limestone on the other hand, was not as accessible in the Copan Valley as in other lowland areas, but nevertheless was obtained from distant outcrops and exploited in great quantities primarily for the manufacture of plaster rather than for masonry.

1.2.2 GEOLOGIC STUDIES OF THE COPAN VALLEY

The Copan Valley is a land of contrasts, encompassing volcanic cliffs, sedimentary hills, floodplains and alluvial terraces containing rich and fertile soils which were exploited for agriculture and construction. The geologic stratigraphy of Copan consists of different layers of rock from various stages in the geologic time line, with alternating beds of tuff and sandstone representing periods of volcanic activity and sedimentation.

The earliest layers which date from the Cretaceous period (136-164 million years ago), predominantly consist of a fine reddish-brown siltstone, followed by a blue-gray limestone. The siltstone is a product of mud, silt and sand transported by the Copan River and deposited throughout the valley. During periods of scarce river sedimentation, almost pure layers of limestone were formed. Subsequently, pressures deep within the earth raised the horizontal layers, shifting them into a vertical position.

During the early Tertiary period (64 million years ago), sedimentation deposited fine grained sandstones in indistinct layers. One type of sandstone is distinguished by its fractured nodular masses in colors of red, yellow, brown, gray, and light green, and the other, a solid yellow. Both types of sandstone contain volcanic detritus and exhibit a tuff-like appearance.

Volcanic activity projecting clouds of ash and pumice produced two types of green-colored tuff throughout the valley.[28] That containing biotite is found throughout the canyon, while the other lacking such minerals is in residual form north of the ruins. A subsequent eruption emitted a tuff with biotite, scattering it throughout the canyon. A thin stratum of river related sediments capped this layer, and was succeeded by another of tuff containing biotite. Several feet of sedimentation covered the last layer of ash, almost entirely filling the valley. The final eruption occuring ten million years ago, discharged a white-colored tuff containing biotite. The uppermost layers of tuff and sediments have remained unaltered in their horizontal position.

Despite a few slight risings, the most substantial geologic activity was effected by the Copan River which eroded the Tertiary filling of the valley, leaving scant evidence of the two valleys that formerly existed. Once at a higher elevation, the river constructed at least two terraces, while the Sesemil ravine formed the alluvial fan serving as the foundation of the present city of Copan.

Of the two types of volcanic tuff, the one lacking biotite was chosen for the construction of buildings and sculpture probably due to its proximity to the site. Flanking the Sesemil ravine, a tuff was found already fractured into rectangular columns which were of an ideal size and shape for the building of several stelae. This tuff is distinguished by its conspicuous blue-green nodules, the presence of which is considered to be arbitrarily present in sculpture. Presumably it was more important for the Maya to secure an easy source of construction material despite the risk of imperfections.

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[28] Volcanic tuff is not to be confused with tufa, a calcareous rock. It has also been erroneously referred to as trachyte, a volcanic rock composed primarily of alkali feldspars, lacking quartz. Mahood attributes the green color to miniscule traces of montmorillonite or celadonite, yet these minerals were not perceptible in X-ray diffraction; Gail Mahood, "Habitat and Agriculture in the Copan Region," *Introduction to the Archaeology of Copan*,, Tegucigalpa D.C., Instituto Hondureno de Antropologia e Historia, 1983: 61.

CHAPTER TWO
PLASTER STUDIES

2.1 PLASTER AS AN ARCHITECTURAL ELEMENT

Plasters have been important architectural elements throughout history, serving both utilitarian and ornamental purposes. Applied on interior and exterior surfaces, plasters act as protective barriers from agents of deterioration, and possess aesthetic value which can be decorative or symbolic. As building components, they reflect the technical and aesthetic sophistication of a culture. As historical documents, plaster-inscribed texts when viewed in situ contribute to the interpretation of historical figures and events.

Lime plaster, a product of calcined limestone, originated the Near East where it was employed as an adhesive ca. B.C. 12,000, and as an architectural material ca. B.C. 10,300.[29] In the New World, its use was confined to Mesomerica, since ca. B.C. 200,[30] and considered to be a distinguishing characteristic from other New World Cultures.[31] Masonry architecture of the Classic period was almost invariably covered in some form of plaster product. The use of lime mortar is thought to have played a significant role in more advanced forms of architecture within Mesoamerica since it was employed ornamentally as well as functionally.[32] Other lime-based building components include

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[29]David Kingery, et al., "The Beginnings of Pyrotechnology, II: Production and Use of Lime and Gypsum," *Journal of Field Archaeology*, Volume 15, 1988: 219. Boynton claims the earliest documented use was about B.C. 4000, when it was used in Egypt for plastering pyramids. Excavations have revealed a two coat lime plaster utilized for mural painting in the Palace of Knossos in Crete in B.C. 1500; Robert Boynton, *Chemistry and Technology of Lime and Limestone*, New York: John Wiley & Sons, Inc., 1966: 388.

[30] Brown asserts that the oldest known lime plasters are from Cuello, Belize which date to 1,200 to 2,000B.C. based on an unpublished work of Edwin Littman. However, they have been backfilled and cannot be confirmed; Gordon Brown, *Analysis and History of Cement*, Ontario, Canada, Gordon Brown, 1996: 73.

[31] In the Old World, gypsum served as the source of cement; Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, and Stuccoes: Comalcalco I," in *American Antiquity*, Volume 23, Number 2, 1957: 135.

[32] Edwin Littman, Ibid: 135.

mortars, stuccos, and wash coats, all of which contributed to the longevity of the masonry buildings.

As primary architectural materials, the Maya used plasters to pave interior floors and exterior plazas. Before the discovery of lime, early Mesoamerican floors consisted of tamped earthen surfaces. Although considered a durable and economic material, earthen floors were susceptible to water damage and harbored insects in a wet or humid environment. The introduction of plaster served to efficiently remove waste and water, thereby providing greater sanitary conditions. At the same time, it was regarded as a more aesthetically desirable material.[33]

Plaster floor construction in the Lowland Maya areas consisted of a rubble fill covered by a layer of lime plaster. Edwin Littman divided floor elements into five layers consisting of a fill, lime aggregate, mortar, plaster, and wash coat.[34] The fill, composed of rubble mixed with sascab, a naturally decomposed limestone, or earth, constituted the initial levelling layer. Capping this was a lime aggregate to function as an intermediate levelling or primary load-bearing layer. Mortar, the final levelling layer, consisted of burned lime mixed with sascab, marl, or earth, and gravel. Plaster served as a smoothing layer, containing burnt lime, combined with sascab or marl, and fine to coarse-sized (if any) aggregates. The wash coat was the thin finish layer made of burnt lime and free of aggregates and may have been burnished.

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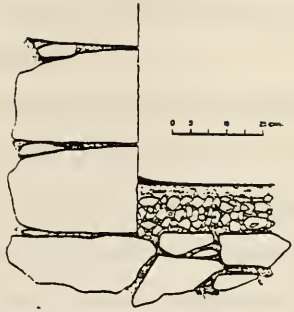
[33]Elliot Abrams, *How the Maya Built Their World*, Austin: University of Texas Press, 1994:34.
[34] Littman notes that not all elements are always present in every floor; Edwin Littman, 'Preliminary Report on Plaster Floors at Cuello," National Geographic Society, 1978: 89.



Floor Section. From Aubrey Trik, "Temple 22 at Copan," (Carnegie Institute of Washington, 1939), 96.

Plaster floors at Copan were described in archaeological accounts as consisting of three separate layers.[35] The base layer, measuring approximately 6 - 8 cm, consisted of small stones and lime, and was applied directly over fill. A second layer measuring 2 - 4 cm, contained a solid layer of lime plaster was superimposed by a thin coat of pure lime and burnished. Floors sloped away from the walls toward the center of the room, leading to doorways to improve drainage.

Plaster quality was found to vary depending on the floor's intended use. Littman suggested that for building foundations the plaster layer may simply have been made up of tamped or water-settled material, such as sascab or marl mixed with clay.[36] Floors intended to provide a surface to walk upon and exposed to weathering required burnt lime for greater durability. As a function of physico-chemical properties evolving over time, evidence suggests that load bearing capacity developed from accumulated experience rather than a knowledge of engineering.[37]. Considering that lime was the principal cementing agent in floor construction, Maya floors exhibit a considerably high structural

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[35] Aubrey S. Trik, "Temple XXII at Copan,"Ibid: 96.
[36] Edwin Littman, "Patterns in Maya Floor Construction," *American Antiquity,* Volume 32, No. 4, 1967: 523.
[37] Edwin Littman, "Preliminary Report on Floor Plasters at Cuello." Ibid.: 90.

strength. Floor plasters which date to nearly 2,000 years ago were found to exceed some modern building code requirements.[38]

Plasters consist of a binder, an aggregate and additives combined in varying proportions according to their intended application.[39] The aggregates and additives provide structure and bulk for the mixture as well as shrinkage control, while the binder is the reactive ingredient responsible for binding and hardening the combined materials. Most plasters contain clay, lime or gypsum as the principle binders, mixed with sand or crushed stone, and additives which vary according to availability. Water is necessary to effect the chemical reaction and provide plasticity to facilitate application.

Distinguishing properties of plasters include the color and chemical composition of the binder; the grain size distribution and petrographic composition of the aggregate; the proportion of aggregate to binder; and the nature and quality of the additives. To a large extent, these properties contribute to the workability, cure strength, bond of the plaster to the substrate, and durability of the plaster. In general, the quality of plaster is a function of the percentage of binder. Previous analyses have yielded the ideal ratio of lime to aggregate ranges between 1:1 and 1:4 by volume.[40]

The technology for manufacturing lime is considerably more complex than that for gypsum or earthen materials.[41] Lime however, yields a more durable, water-resistant, and impermeable product and is therefore better suited as a flooring material. It is a labor intensive process, involving several interrelated activities. The herculean efforts required

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[38] David Hyman, Ibid: 6-7. Roys, on the other hand, claims that none of the Maya cements were comparable in strength to Portland cement or modern lime mortar; Lawrence Roys, "The Engineering Knowledge of the Maya," *Contributions to American Archaeology*, No. 6, May 1934: 96.

[39] Earl Morris, *Temple of the Warriors*, Washington, D.C.: Carnegie Institute of Washington. 1931: 223.

[40] Morris contends that sascab represented 75% of the plaster's volume; Earl Morris, *Temple of the Warriors at Chichen Itza*, 1931: 223. Roys found the proportion of aggregates to make up 67% of the plaster. Lawrence Roys, *The Engineering Knowledge of the Maya*, 1934: 97.

[41] According To Hyman, gypsum plaster requires a heat of 266 to 392F. Gypsum = Calcium Sulfate ($CaSO_4 + 2H_20$). The degree of dehydration determines whether the plaster becomes either 1) Plaster of Paris ($CaS0_4 + H_20$) or 2) Flooring Plaster ($CaS0_4 + 2H_20$). Earthen plaster does not require a calcination process. David Hyman, "Pre-Columbian Cements", John Hopkins Master's Thesis, 1970: 2-4.

for procuring copious amounts of fuel wood to maintain high firing temperatures;[42] erecting an open air kiln or "calera"; quarrying and transporting limestone; collecting and crushing the aggregate; and accurate proportioning, makes plaster manufacturing the costliest and most complex factor in masonry construction undertaken by the Classic Maya.[43]

Lime is produced from the calcination of limestone, which in its "pure" form is calcium carbonate ($CaC0_3$). Most limestones contain impurities such as quartz, clays, feldspars, gypsum, and carbonates of other metals, notably magnesium.[44] Magnesium limestones which consist of magnesite, calcite, and dolomite are also common. When heated to a sufficiently high temperature (approximately 800°-900°C), the calcium carbonate decomposes into carbon dioxide and as finely powdered calcium oxide, known as quicklime.[45] With the addition of water, a process termed "slaking" or hydrating, a chemical reaction releases heat, causing the mass to expand to two or three times its original volume.[46] After slaking for a minimum of 24 hours[47], the mixture yields a product known as slaked lime calcium hydroxide. Exposure to the air as plaster or mortar allows

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[42] Kingery estimates that for each ton of lime production in an open pit firing kiln, at least four tons of wood fuel and two to three tons of limestone are required. Kingery et al., Ibid: 219.

[43] Eliot Abrams, Ibid.: 264. Garfinkel suggests that the technical obstacles which have to be overcome to produce plaster make it a limited commodity, much like exotic objects, Yosef Garfinkel, "Burnt Lime Products and Social Implications in the Pre-Pottery Neolithic B Villages in the Near East," In *Paleorient*, Volume 13/1, 1987: 72.

[44] Boynton discusses two classifications of limestone impurities, 1) homogeneous, such as silt, clay, and sand which uniformly contaminate the stone upon deposition, and 2) heterogeneous, which collect in the crevices or between strata such as siliceous pieces or nodules of sand, chert or flint which are loosely embedded. This is the source of silica and alumina, the major impurities. The presence of minute carbonaceous impurities, which impart a gray color to the limestone, volatizes upon calcination. Iron oxides give a warm tint to the limestone. Robert Boynton, Ibid: 17.

[45] The dissociation temperature has been established for calcite at 898° (1648° F). Dissociation proceeds from the outside surface inward. In order to penetrate the interior of the limestone higher temperatures are necessary and elevated for dissociation to occur. The larger the diameter of the stone, the higher temperature that is required due to increasing internal pressure as carbon dioxide gas forces its escape. Overburning of quicklime may yield a faint yellowish cast in the resulting hydrate. Boynton, Ibid: 133-4.

[46] Abrams claims that as much as 32% by weight of water is added to complete the slaking process. "The Evolution of Plaster Production," in *Arqueologia Mesoamericana: Homage a William T. Sanders*, INAH, 1996: 197.

[47] Abrams cites that two weeks was the minimum time to wait before the lime was sufficiently slaked; Abrams, Ibid: 200.

the evaporation of water and adsorption of carbon dioxide, thus hardening to a solid mass. The product remains chemically identical to its source, yet possesses a distinguishable internal crystal structure.[48]

Archaeological studies suggest the ancient Yucatan method of producing lime was implemented at Copan, as recounted by Earl Morris during his work the Temple of the Warriors at Chichen Itza.[49] (Figure 4) The process commenced with the erection of a *calera* consisting of a 2 meter high cylindrical pile of freshly cut timber radiating around a center pole. A layer of quarried limestone chunks, measuring 0.5 - 0.75 meters thick, were placed on the wooden pyre. With the center pole removed, the base was ignited to calcine the limestone, transforming it into a fine white powder within 24-30 hours. The exposure to moisture from dew and rain slaked the powder, causing it to expand approximately 5-6 times its original volume.[50] To obtain the highest quality plaster, the lime was stored for periods up to a year to ensure sufficient hydration.

Since pure lime plaster is relatively weak, aggregates are added to increase strength and reduce shrinkage. The content and types of sand included are critical factors in plaster preparation. Angular sand particles provide friction, generating a stronger bond between the binder and aggregate.[51] A smoother, finer particle enhances the mobility of the mix to effect greater workability. Therefore, a more "plastic" plaster does not require as much water, reducing the possibility of shrinkage and cracking. Including particles of various sizes is necessary so that the voids left between the larger particles are occupied

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[48] The microstructure of lime plaster consists of submicron spherical particles, in contrast to the chunky calcite grains of limestone. It also depends on the geological conditions of deposition and consolidation of the limestone; David .Kingery et al, Ibid: 221.

[49] Earl Morris, *Temple of the Warriors,* Ibid: 220. Abrams suggests there is no empirical data from any southern Lowland site indicating the use of caleras by the Classic Maya. Eliot Abrams, "The Evolution of Plaster Production and the Growth of the Copan Maya State," 200.

[50] Eliot Abrams states the amount of lime produced also varies according to the rate of slaking and the percentage of impurities in the limestone. Ibid: 200.

[51] Boynton asserts the superiority of limestone aggregates to gravel due to its sharp, angular and chunky shape which produces a stronger bond and greater density with the fine aggregates than the smooth, rounded shape inherent to sand. Boynton, Ibid: 118.

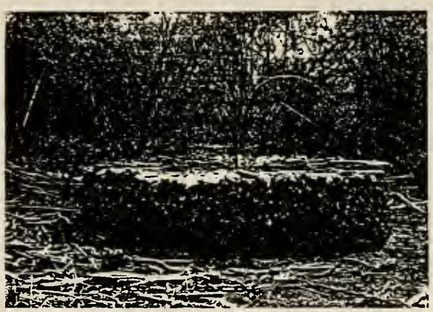

FIG. 133—CYLINDER OF WOOD FOR LIME BURNING, HALF BUILT

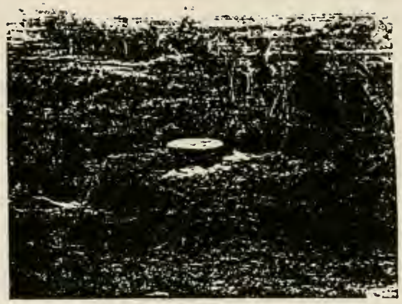

FIG. 134—COMPLETED CYLINDER OF WOOD FOR LIME BURNING

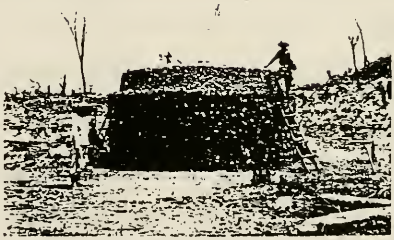

FIG. 135—CYLINDER OF WOOD SURMOUNTED BY BROKEN STONE, READY FOR FIRING

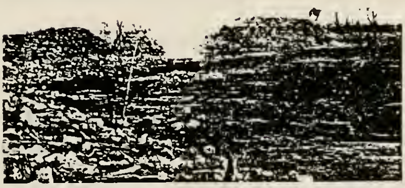

FIG. 136—LIME HEAP BURNING

FIG. 137—LIME HEAP AFTER BURNING

Figure 4. Yucatecan Method for Lime Burning. From Earl Morris, *Temple of the Warriors at Chichen Itza*, (Washington, D.C.: Carnegie Institute of Washington, 1931), 221.

by the smaller ones.[52] Since larger particles possess less total surface area for bonding with the binder than smaller particles, it is not possible to obtain high strengths with only coarse size aggregates.[53] Therefore, a well graded material with a representative amount of various sizes will yield better workability and ultimately greater durability. Aggregate quantity is also an important factor, since oversanding as well as undersanding will produce a weaker plaster.

The relative proportions of aggregate particles, known as grain size distribution, influences a plaster's behavior and suitability as a building material. Aggregates are composed of different shapes and sizes which represent the formation and weathering of the parent rock. The following grain size convention based on the American Society for the Testing of Materials (ASTM) standards, are used in the current study:[54]

clay:	particles smaller than 0.002 mm (2 μm).
silt:	particles between 0.002 mm and 0.02 mm.
fine sand:	particles between 0.02 mm and 0.075 mm.
coarse sand:	particles between 0.075 mm and 4.75 mm.
gravel:	particles between 4.75 mm and 76.2 mm.

Since sand was generally scarce in the Maya area, *sascab*, calcium carbonate in an unburnt state, was reported to be used in nearly the same proportions as sand in modern mortars.[55] Referred to in earlier accounts as 'white earth'[56] or 'lime dust,'[57] sascab is the

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[52] Paolo and Laura Mora, *Conservation of Wall Paintings*, London: Butterworths, 1984: 52.
[53] Joseph Galloway, Jr., "Grading, Shape and Surface Properties," in *Significance of Tests and Properties of Concrete and Concrete Making Materials*, Philadelphia: ASTM, 1990: 404.
[54] "D 422: Standard Test Method for Particle-Size Analysis of Soils." (Philadelphia: ASTM, 1993) and "D 653: Standard Terminology Relating to Soil Rock, and Contained Fluids," Philadelphia: ASTM, 1993.
[55] Lawrence Roys, *Engineering Knowledge of the Maya*, Ibid: 97; Earl Morris cites the proportions of 1 lime to 2 sascab in *Temple of the Warriors*, Ibid: 220.
[56] Alfred Tozzer, *Landa's Relacion de las Cosas de Yucatan*, Ibid:18.
[57] Earl Morris, *Temple of the Warriors*, Ibid: 223.

product of the natural weathering of limestone, and found in pockets underneath the caprock. Its use was often preferable to burned lime in that it economized on labor and original construction material.[58] Evidence reveals that sascab floors were present in the Maya region for hundreds of years prior to the Christian era and found in plasters as late as A.D. 800.[59] Examinations of plaza floors and roads in the Yucatan indicate that sascab was employed as a protective layer for maintenance purposes. The natural cementing action of the rain, in addition to various pressures, produced a considerably durable pavement.[60] Its use is thought to have diminished as lime production became more widespread.

A distinguishing feature of plasters from Copan and Tikal is the inclusion of volcanic tuff as an aggregate. Presumably detritus collected from masonry block construction was crushed to make aggregate material. In some cases, the tuff was found to occupy almost fifty percent of the plaster's volume.[61] Tuff, of which the Copan structures were constructed, was a likely choice since outcrops are located less than one kilometer from the site, in comparison to limestone which is situated approximately ten kilometers away.[62] Tuff weighs significantly less than other stone aggregates and is therefore easier to transport and work into the lime mixture which ultimately reduces the unit weight of the plaster.[63] It is also preferable to other aggregate types in that a superior bond with the lime is achieved by virtue of its porous surface.

The addition of certain volcanic constituents can sometimes impart hydraulic poperties to binders, enabling them to set under water. A chemical reaction occurs among

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[58] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, and Stuccoes: Floor Construction at Uaxactun," in *American Antiquity*, Vol. 28, No. 1, 1962: 101. It may be the case at Copan where limestone outcrops are remote, yet it has not been proven.
[59] Gordon Brown, *Analysis and History of Cement*, Ibid: 76.
[60] Sylvanus Morley, *The Ancient Maya*, Palo Alto: Stanford University Press, 1956:
[61] David Hyman, *Pre-Columbian Cements*, Ibid: A-82.
[62] Hyman suggests the possibility of using volcanic rocks for religious purposes but does not elaborate on that issue; David Hyman, Ibid:
[63] David Hyman, *Pre-Columbian Cements*, Ibid.: A-83.

the various elements, such as silica, alumina and iron, which are present in specific proportions, to eventually form crystalline silicates. This feature has not been associated with pre-Columbian Maya plasters.[64]

Ethnohistoric accounts report the widespread use of organic additives for the purpose of enhancing certain properties of plasters. Modern Maya masons continue this practice for increasing the workability or strength of the plaster and to reduce cracking.[65] The earliest known account reports that bark extracts were used for the purpose of polishing and hardening plastered surfaces.[66] Plant gums were also identified in Late Classic mural plasters, presumably to alleviate the deleterious effects of a humid environment.[67]

Morris attributes the hardness of roof and floor surfaces to the inclusion of bark extracts, in addition to tamping the plasters with wooden mauls.[68] The process involved stripping the bark of the chocom tree and soaking it in a vat of water for a number of days. Lime was amended with the liquid and applied with a trowel, resulting in a surface with a "magnificent polish and practically impervious to water."[69]

2.2 EARTHEN PLASTERS

Since two of the study floors are composed of soil, a brief discussion of earthen plasters is appropriate. Earthen plaster, also termed clay or mud plaster, is the oldest known render, traditionally employed as a surface coating for earthen walls.[70] Soil and

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[64] Ibid: 6-5.
[65] Edwin Littman, Ancient Mesoamerican Mortars, Plasters, and Stuccoes: Camalcalco Ibid: 136.
[66] Alfred Tozzer, Ibid.: 175-6.
[67] Diana Magaloni et. al, "Studies on the Mayan Mortars Technique," *Materials Issues in Art and Archaeology,* Ibid: 49.
[68] Earl Morris, *Temple of the Warriors*, Ibid: 224.
[69] Earl Morris, Ibid. 224.
[70] Clough Williams-Ellis; John and Elizabeth Eastwick-Field, *Building in Cob, Pise and Stabilized Earth*, London: Country Life Limited, 1919: 103.

water are the primary components of earthen plasters. Soil consists of sand, silt, and clay particles in varying proportions which provide the bulk of the plaster. Sand primarily ads bulk and helps to minimize shrinkage and cracking. Clay, and to a limited extent silt, are the binding mediums which serve to cohere the soil particles together and in effect, influence the soil's performance.

Clay minerals are hydrous aluminosilicates produced by the disintegration and chemical decomposition of sedimentary rocks and some types of metamorphic rocks. Clays form when silicate minerals interact with water causing an exchange of cations for hydrogen ions. The process, known as hydrogen exchange, causes the material to alter at variable rates, resulting in a soil consisting of altered minerals from the parent rock and some original minerals in an unaltered state.[71]

Classified as fine-grained minerals whose particle diameters are less than 0.002 mm (2μm), clays cannot be resolved by the petrographic microscope. Furthermore, since clay-bearing sedimentary rocks often contain more than one type of clay mineral, analytical techniques such as X-ray diffraction, differential thermal analysis, and infrared spectroscopy to enable their identification. Other distinguishing characteristics include their mineral composition and crystal structure.

Mineralogy of the clay fraction plays a role in soil behavior.[72] Clays exist in a lattice structure of alternating layers of aluminum oxide (Al_2O_3) and silicon oxide (SiO_2), joined together by strong (covalent) bonds. As phyllosilicates, their sheeted structure provides them with a greater surface area than cubic or spherical-shaped minerals of the same size. A larger surface area relative to the volume of the particle permits adsorption of water and other substances to their surfaces. The resultant hydrogen bond imparts

[71] Bruce Velde, "Composition and Mineralogy of Clay Minerals," in *Origin and Mineralogy of Clays*, Germany, Springer-Verlag Berlin Heidelberg, 1995: 5-7.
[72] Giorgio Torraca, Porous Building Materials: *Materials Science for Architectural Conservation*, 3rd edition, Rome, ICCROM, 1988: 97.

excellent cleavage and a greater compaction than other minerals because of the parallel stacking of layers.

The layered crystal structure allows clay particles to slide past each other upon exposure to water so that clays can be easily shaped when wet and retain their shape upon drying. As components of earthen plasters, clay act as the binding medium which hold the more inert materials together. Different types of clays have varying capacities to adsorb water or expand in its presence, and therefore will determine the behavior of a soil. A high clay content for example, will increase the likelihood of cracking upon drying and may inhibit adhesion to the substrate.

The three major clay groups include montmorillonites (also called smectites), kaolinites, and illites.[73] Kaolin, a common clay mineral of the kaolinite group $[Al_2Si_20_3(0H)_4]$, is composed principally of alumina and silica in a two-layered structure. It does not readily react in the presence of water due to its stable structure, and contains few impurities. Strong hydrogen bonding and a distance of 1Å between its sheets gives it stability and prevents water from penetrating or swelling the crystals. Illite $[KAl_2(AlSi_30_{10}(0H)_2]$, with its three level structure of 10Å apart, is a more active clay that adsorbs water into its outer layer, causing moderate swelling. Montmorillonite $[Al_2Si_40_{10}(0H)_2]$, also has a three level crystal structure of 14-30Å apart, but is more volatile. Its weak interlamellar bonds are more susceptible to swelling and shrinkage.

Sand generally consists of silica and other eroded minerals in sizes which vary between 0.02 - 4.75 mm. When used in plasters, they provide bulk and friction and contribute to hardness and durability. Silts are essentially small sand particles, ranging between 0.002 - 0.02 mm, when viewed from a physical and chemical perspective.[74] Due to their smaller size, they provide bulk, increase friction, and thus improve cohesion of the plaster.

[73] Nyle Brady, *The Nature and Properties of Soils*, New Jersey, Prentice-Hall, Inc., 1996: 233.
[74] CRATerre, "Soil Encyclopedia," (photocopy): 25-27.

2.3 PREVIOUS PLASTER STUDIES IN THE MAYA REGION

The use of lime plaster and stucco for utilitarian and decorative purposes is one of the several characteristic traits of Mesoamerican culture.[75] As such, plaster products contribute to our understanding of the Maya civilization with respect to their function as building components and as indicators of social and economic phenomena.[76]

Perceived as secondary materials whose role in architecture is primarily non-structural, plasters have not received the attention and conservation efforts traditionally afforded to primary architectural materials. Much of the literature gives plasters more descriptive than compositional and structural consideration. In the last twenty years, plasters have increasingly been recognized as a material worthy of analysis which has helped to resolve archaeological issues regarding the availability of resources, diachronic and synchronic variations in materials and construction techniques, technological complexities, and the importance a society places on these materials.

The most comprehensive chemical analyses of Mesoamerican lime-based materials were conducted between 1957 and 1973 by Edwin Littman who distinguished mortars, plasters, and stuccos based on their function and aggregate content. He defined mortar as a bonding material layered between stone courses, containing a fine to coarse-sized aggregate; plaster, a protective medium or surface for mural painting, consisting of a fine-sized aggregate; and stucco, used for decorative or symbolic purposes, which is similiar to plaster in density and appearance but contains little or no aggregates.[77]

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[75] Edwin Littman, "Mesoamerican Mortars, Plasters, and Stuccos, Camalcalco, Part I," in *American Antiquity*, Volume 23, Number. 2, 1957: 135.
[76] Yosef Garfinkel, "Burnt Lime Products and Social Implications in the Pre-Pottery Neolithic B Villages in the Near East," Ibid: 72.
[77] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, and Stuccoes: Comalcalco, Part I," Ibid: 136.

Littman observed a pattern of Maya floor construction existing from the Pre-Classic to Post Classic periods. Plaster floors were described as consisting of a foundation covered with coarse stone in a matrix of mortar or finely divided material, and capped with a more impermeable layer of plaster.[78] However ubiquitous this practice was, Littman observed variations in construction techniques throughout the Maya region. Elemental analysis of plaster layers revealed a multilaminate structure at Comalcalco for example, and an absence of such found in the Puuc area.[79] However, evidence indicates floor construction techniques were not necessarily independent ventures since the composition of early floors from distant sites share common traits, such as the use of burnt clay. [80]

To determine whether or not changes in floor construction reflect technical improvements, Littman observed a sequence of pavements which represent a long, uninterrupted period of occupation. Investigations of building elements at Las Flores, Tampico indicates that the upper strata of floors were virtually free of carbon. This represents a technical advancement in that the Maya were able to produce a purer form of lime.[81] Similiarly, the quality of floors at Tikal were found to improve from the Pre-Classic to Classic periods with respect to hardness, mechanical structure and durability.[82]

Modifications in floors were rarely abrupt but were found to correspond with changes in utilitarian objects or other building elements. At Uaxactun for example, technical advancements in floors were observed to coincide with stylistic changes in pottery.[83] Rounded aggregates, a water-borne material, were replaced by stone chips,

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[78] Edwin Littman, "Patterns in Maya Floor Construction," Ibid: 523.
[79] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, and Stuccos: Camalcalco, Part 1," Ibid: 139.
Edwin Littman, "Maya Floor Construction," Ibid: 532.
[81] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters and Stuccos, Las Flores, Tampico," *American Antiquity*, Volume 25: 117-119.
[82] Edward Littman, "Observations on Floors of Platforms 5D-1 and 5D-4," *Tikal Report, Number 14*, Michael Coe, Editor, 1962: 999.
[83] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters and Stuccoes, Floor Construction at Uaxactun," in *American Antiquity*, Volume 28, No. 1 1962: 100.

representing a departure from relying on naturally available raw materials towards incorporating a man-made and improved product.[84] Floors at the Altar de Sacrificios were found to have evolved from a foundation of earth and shells to one comprised of plaster and stone, commensurate with the transition from earthen pyramid construction to the use of stone as a structural material.[85]

The presence of various plaster constituents may simply reflect the availability or limitations of resources in a particular area. David Hyman surveyed calcareous cements from several sites throughout Mesoamerica and observed aggregates of a volcanic origin present in plasters throughout Mexico, and at Copan and Tikal within the Maya area.[86] Eric Hansen et al, submit that in the southern Lowland Maya region, the cement matrix and aggregates were generally derived from limestone alone, which is in contrast to most Mesoamerican sites where plasters include a variety of materials as aggregates.[87] At Las Flores where stone was not easily accessible, the foundation of floor plasters consisted of natural or burnt earth mixed with materials such as shells, sherds, burnt grass, or twigs for improved permeability.[88] Shells were found in plasters to serve as an aggregate and not, as previously believed, to be a source of lime.[89] From his observations of plasters in thin section, Hyman was able to distinguish microfossils and the size and degree of rounding of limestone grains. Consequently, he was able to discern the environment in which the limestone was formed and suggest its possible sources.[90]

Elliot Abrams suggests the likelihood of recycled plaster being used in plaster products at Copan and other sites.[91] Since buildings were continually being demolished

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[84] Edwin Littman,"Ancient Mesoamerican Mortars: Floor Construction at Uaxactun," Ibid: 101.
[85] Edwin Littman, "Maya Floor Construction," Ibid: 530.
[86] David Hyman, "PreColumbian Cements," Ibid: 6-8.
[87] Eric Hansen, personal correspondence, May 1997.
[88] Edwin Littman, "Maya Floor Construction," Ibid.: 525.
[89] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, and Stuccoes: Sascab," In American Antiquity, Vol. 24, No. 2, 1958: 176.
[90] David Hyman, Ibid.: 6-8.
[91] Eliot Abrams, "The Evolution of Plaster Production and the Growth of the Copan Maya State," Ibid: 198.

and built upon, he postulates that plaster roofs were crushed and resued in the manufacture of new plaster. This phenomenom is strongly implied since sizable roof fragments were not found in the fill of superimposed structures.

In examining Neolithic plasters from the Near East, Yosef Garfinkel found improvements in the physical properties of plaster floors tend to concur with social and economic conditions.[92] He proposed that changes reflect the status of employment and specialization of labor since a larger work force and/or greater efficiency in the production of lime were increasingly required.

Similarly, the significant increase in the volume of architecture built during the Middle and Late Classic periods at Copan corresponded with the expansion of state level power.[93] This growth, with the demands of the burgeoning elite for conspicuous architectural symbols of power is reflected in the expanded scales of architecture.[94] Since plaster was an integral component of masonry architecture, a change in production technology was undoubtedly required.

Economic or social changes occuring at the time of construction are often perceivable in plasters by the inclusion of certain constituents, such as recycled materials or the absence of burnt lime, indicating a possible shortage or exhaustion of materials. Diana Magaloni et al. demonstrated by their analysis of plasters supporting murals at Teotihuacan, that materials and stylistic transformations coincided with social changes described in archaeological accounts. The introduction of different types of aggregates exhibiting refinements in their proportion, shape and distribution suggest the initiation of an improved technique for plaster manufacture.[95]

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[92] Yosef Garfinkel, Ibid: 72.
[93] Robert Sharer, "Evolution of Classic Period Architecture in the Eastern Acropolis," Ibid. 1992: 148.
[94] Elliot Abrams, "Evolution of Plaster Production.." Ibid. 1994: 198.
[95] Diana Magaloni et al, "Electron Microscopy Studies of the Chronological Sequences of Teotihuacan Plaster Technique," in *Materials and Issues in Art and Archaeology III,* Volume 267, Materials Research Society, 1992: 1005.

Plaster investigations supplemented with historical and archaeological data have illuminated the occurence of cultural behavior. For example, historical documents recounted rituals which took place in specified areas of the Templo Mayor in Mexico. Luis Barba et al. confirmed this by testing the intensity and distribution of residual chemical compounds found in plasters located where ritual ceramic burners were excavated.[96]

In the absence of a chronological context, technological innovations in plaster manufacture serve as a relative dating technique. Modifications, such as the introduction of wash coats on floors, indicate an empirical knowledge of the benefits by protecting the substrate. Villegas and Vazquez observed evidence of improved methods in plaster preparation which enabled them to date the stucco reliefs at Palenque. They observed a reduction in grain size to improve workability, from which they were able to seriate plasters based on technical advancements. This is because the smaller grains suggest improvements in grinding methods; an increasingly balanced distribution of aggregate sizes to enhance mechanical resistance; and a refinement in grain/matrix proportions to produce a more durable plaster.[97] Additionally, Magaloni et al. proposed an independent chronology for the Teotihuacan mural paintings based on changes in plaster structure and composition. Littman was surprised to find the presence of limestone aggregates in a building element from Palenque, an area abundant with limestone to burn. This led him to conclude their inclusion represented a technique solely associated with a specific period.[98]

The use of sascab as a substitute for sand in the preparation of Mesoamerican plasters has been cited in ethnohistoric accounts since the sixteenth century. Sascab, as

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[96] Luis Barba et al, "Stuccoed Floors: A Resource for the Study of Ritual Activities: The Case of Templo Mayor, Mexico," in *Materials Issues in Art and Archaeology IV, Cancun, Mexico, May 16-20, 1994*. Materials Research Society, Pittsburgh, PA, 1994: 723.
[97] Mercedes Villegas and Ximena Vazquez, "Relative Dating of the Stucco Reliefs at Palenque, Chiapas, Based on Variation in Material Preparation," in *Materials in Art and Archaeology IV, Cancun, Mexico, May 16-20, 1994,* Materials Research Society, 1995: 471.
[98] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, and Stuccoes: Palenque, Chiapas" *American Antiquity*, Volume 25, Number 2, 1959: 114.

described by Littman, is a product of the natural weathering of limestone, and is chemically identical to its parent rock.[99] Microscopically, sascab displays a crystalline structure and varies in color from white to translucent, and sometimes red given the presence of iron oxide.[100] It is considered to be indigenous to Central America and the Yucatan, and its use is common in plasters before the development and widespread manufacture of lime.[101]

Plasters consisting of compacted sascab were generally more susceptible to erosion than those containing lime.[102] However, those coated with a lime wash, such as the sascab plasters found at Uaxactun, exhibited considerable impermeability due to their carbonated surface.[103] The grain size of sascab was also found to be a contributing factor in the compressive strength of plasters which ranged from 860 to 2,000 psi.[104]

The durability of sascab plasters can be ameliorated by protective membranes found on their surfaces. Plasters consisting of sascab displayed sufficient porosity to allow the ingress of moisture, often resulting in the surface growth of algae or lichen which prohibited further moisture penetration. Additionally, cuprous oxide, a natural soluble mineral observed in sascab, was found to migrate to the surface and recrystallize into a semi-translucent green deposit, keeping the substrate intact.[105]

Sascab was purportedly used in quantities ranging between 50-75% of the calcium carbonate content.[106] However, obtaining accurate ratios of sascab to lime is difficult

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[99] Edwin Littman, "Sascab," Ibid: 172.
[100] Ibid. 172.
[101] Gordon Brown, *Analysis and History of Cement*, Ibid: 75.
[102] Ibid: 75.
[103] Edwin Littman, "Ancient Mesoamerican Mortars: Floor Construction at Uaxactun," Ibid: 100.
[104] Gordon Brown, "Mortars for Tropical Archaeological Sites," in *Association for Preservation Technology Bulletin*, Volume XIX, No. 3, 1987: 43.
[105] Gordon Brown, Ibid.: 75.
[106] In the Puuc region, Littman observed that only the necessary amount of lime was included, stating that "...only minor amounts of burned lime were necessary to secure satisfactory mortars and plaster;" Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, Stuccoes, the Puuc Area" in American Antiquity, Volume 25, 1960: 409. Supporting this conclusion is Littman's analysis of plaster floors at Uaxactun revealing a large proportion of aggregate related to lowering the cost of plaster manufacture. He states, "The use of easily compacted sascab or marl as a floor plaster in preference to burnt lime represents a

either by gravimetric methods due to the acid solubility of both components, or the lime point count method because of the difficulty in distinguishing the two materials by optical microscopy.[107] Distinguishing sascab from burnt lime by testing the depth of carbonation is ineffective because the sascab lies deeply embedded in the lime matrix. Although unable to provide a definitive test to measure the proportion of sascab to lime, Littman suggested the presence of sascab was identifiable by limestone aggregates in rounded shapes and the absence of carbon in the matrix.[108]

Hyman revealed in his examinations of Mesoamerican plasters that sub-rounded limestone particles of various sizes were not obtained by the fracturing of larger rock fragments, but suggested the presence of sascab.[109] Abrams observed only angular particles in Copan plasters, supporting his claim that only sand, quarried limestone or recycled plaster was used as an aggregate. Moreover, he contended that sascab is either scarce or non-existent in the Copan Valley.

The widespread use of organic additives in the manufacture of Maya plasters has been reported from ancient to modern times .[110] Bark extracts derived from the *chacte (Caesalpinia platyloba), jabin (Pescidia communis), chocum (Pithecolobium albiacans)* and *chacah (Bursera simaruba)*trees were believed to increase the workability and strength of the plaster and aid in the reduction of cracking.[111] Littman's experiments with tannin obtained from various barks in reduced shrinkage by at least 50%, and increased the gloss and hardness, particularly with the chacte and chacah varieties.[112] Abrams suggests

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distinct savings in labor as well as construction material," Littman, "...Floor Construction at Uaxactun," Ibid: 101.

[107] Gordon Brown, personal correspondence, May 1996.

[108] In three floor samples from Copan, Hyman suggests the presence of pisolites, a coarse grained oolite, which is part of the limestone matrix. He does not mention the presence of sascab in these particular plasters; Edwin Littman, "Sascab," Ibid: 175.

[109] David Hyman, "Pre-Columbian Cements," Ibid: S-4.

[110] Gordon Brown, *Analyses and History of Cements*, Ibid: 77.

[111] Edwin Littman, "The Use of Bark Extracts in Lime Plasters," in *American Antiquity,* Volume Volume 25, Number 4, 1960: 593.

[112] Edwin Littman, Ibid.: 594.

that the brownish color of the plaster may be attributed to the inclusion of a bark extract, however it is not yet conclusive.[113] Other organic additives, such as honey, were reportedly used in the plasters and mortars at Uxmal,[114] and there is speculation about the inclusion of eggs or plant extracts in the plasters of Palenque.[115] Magaloni et al., found organic materials in lime plasters from several archaeological sites. Analyses employing scanning electron microscopy revealed that various organic additives promoted a crystallization network with the calcium carbonate which improved the mechanical properties of the plasters, possibly as a result of the acidic nature of the additive.[116] Hyman suggested bark extracts served as a curing catalyst but found their presence limited to stuccoed finishes.[117]

[113] Eliot Abrams, Ibid: 194: 196.
[114] Edwin Littman, "Ancient Mesoamerican Mortars, Plasters, and Stuccos: Camalcalco, Part I," Ibid: 136.
[115] Edwin Littman, "Ancient Mesoamerican Mortars: Palenque, Chiapas," Ibid: 265.
[116] Diana Magaloni et al., "Studies on the Mayan Mortars Technique," Ibid: 489.
[117] David Hyman, "Pre-Columbian Cements," Ibid: 6-14.

CHAPTER 3
THE COPAN ACROPOLIS

3.1 ARCHAEOLOGY AT COPAN

"...here was formerly the seat of a great power and a great population, civilised and considerably advanced in the arts as is shown in the various figures and buildings."

So wrote Don Diego de Palacio to King Philip II of Spain in describing the Copan ruins upon his arrival in 1576. Some three hundred years later it was brought to worldwide attention through the writings of John Lloyd Stephens and illustrations by Frederick Catherwood in their book, *Incidents of Travel Through Central America* (1843), *Chiapas and Yucatan.* Several publications followed which spurred interest in the site including Alfred Maudslay's *Biologia Centrali Americana*(1889-1902), Sylvanus Morley's *The Incriptions of Copan*(1920), and George Gordon's *Prehistoric Ruins of Copan* (1896).

Of the Classic period Maya centers, Copan was the site of the first excavation campaign undertaken by the Peabody Museum of Harvard University from 1891 to 1894. Archaeologists entreated by the Honduran government cleared and recorded the structures and sculptures. Among their most significant discoveries was the Hieroglyphic Stairway, revealing the longest inscibed text in the New World.[118]

The twentieth century sparked a new era of archaeological research in the Maya area. Several programs integrating excavation and restoration were initiated with the aim of investigating various aspects of a site.[119] In the course of several campaigns between 1935 to 1946, archaeologists from the Carnegie Institute of Washington concentrated on

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[118] George Gordon, *Prehistoric Ruins of Copan, Honduras.* Memoirs of the Peabody Museum of Archaeology and Ethnology, Vol. 1, No. 1, Cambridge, MA: Harvard University, 1896: 10.
[119] Jeremy Sabloff, *The New Archaeology and the Ancient Maya*, W.H. Freeman & Company, 1990: 158.

excavation, conservation, and restoration. In addition to Sylvanus Morley's interpretation of hieroglyphic texts, one of their most important contributions was the rechanneling of the Copan River to prevent further erosion of the Acropolis' eastern border.

The Peabody Museum, under the direction of Gordon Willey (1975 - 1977), instituted a long-term, multi-disciplinary research program, focusing on the settlement patterns of the Copan Valley and an archaeological survey of the Principal Group. Subsequent programs sponsored by the Instituto Hondureño de Antropològia and Historia (IHAH) included Proyecto Arqueològia Copán (PAC I), directed by Claude Baudez (1977 -80) and PAC II, led by William Sanders of Penn State University (1980 - 85), both of which continued investigations of valley settlement patterns. Further settlement work was undertaken by William Sanders and David Webster (1986 - 89), Wendy Ashmore (1988 - 89), and David Webster (1990). In 1995, the Copan Mosaics Project was initiated by William and Barbara Fash to interpret, conserve, and reconstruct the extensive corpus of fallen mosaic sculptures from masonry structures.

Current investigations of the various structures are conducted under the aegis of the Proyecto Arqueològico Acrópolis Copán (PAAC) which constitutes the most comprehensive efforts undertaken at Copan. Collaborating with PAAC since 1989, the Early Copan Acropolis Program (ECAP), under the guidance of Robert Sharer, aims to document the Acropolis complex and preserve the final construction phase.[120] Incurring minimal destruction, over 2 kilometers of tunnels have been excavated in order to expose various construction phases dating to the Early Classic period. The interpretation of architectural stratigraphy, supplemented by accurate dating methods and hieroglyphic deciphering, has illuminated the development of the Acropolis from its dynastic founding

[120] Support for ECAP research has been provided by the facilities and personnel of IHAH and research funding from the University of Pennsylvania Museum, the National Geographic Society, the Foundation for the Advancement of Mesoamerican Studies and several private donors; Robert Sharer, Julia Miller, and Loa Traxler, "Evolution of Classic Period Architecture in the Eastern Acropolis, Copan," in *Ancient Mesoamerica*, Volume 3, 1992: 148.

through the Late Classic period. The excavations of Structure 10L-16, led by Ricardo Agurcia, and the Cemetary Group, directed by E. Wyllys Andrews are both in progress.[121] Overall, the series of investigations and cumulative research focused on Copan represents the longest and most intensive efforts conducted at any Maya site.

3.2 CHRONOLOGY OF THE COPAN ACROPOLIS

Copan may be aptly called 'the Athens of the New World,'...it may be claimed with perfect assurance that no other city of aboriginal America ever attained so high a level of cultural achievement.[122]

The Copan Acropolis was the center of the site's architectural development during the Classic period (ca. A.D. 420-820), consisting of palaces, temples, and administrative buildings occupied by Copan's ruling families (Figure 5).[123] In the Maya region, an "Acropolis" is defined as an architectural concentration (usually a group of buildings) which has evolved into a single, elevated and monumental complex.[124] In sheer constructional mass, Copan is the largest center in the southeastern Maya Lowlands.

The Acropolis is the heavily built up area in the southern portion of the site. To the north are open plazas, including the Great Plaza, surrounded by smaller structures. The final Acropolis is divided by the East and West Courts, between which is the largest building, Structure 16. Structure 22 and several smaller structures are situated on the north side of the East Court. Further north stands Structure 26, the renowned

[121] Robert Sharer, *The Ancient Maya,* Palo Alto: Stanford University Press, 1994: 300.
[122] Sylvanus Morley, *The Inscriptions at Copan*, Carnegie Institution of Washington (Publication 219), Washington, D.C., 1920: 431.
[123] Robert Sharer, *The Ancient Maya,* Stanford, CA: Stanford University Press, 1994: 297.

[124] Robert Sharer et al., "Early Classic Royal Power in Copan: The Origins and Development of the Acropolis (c. 250-650AD)," Ibid: 6

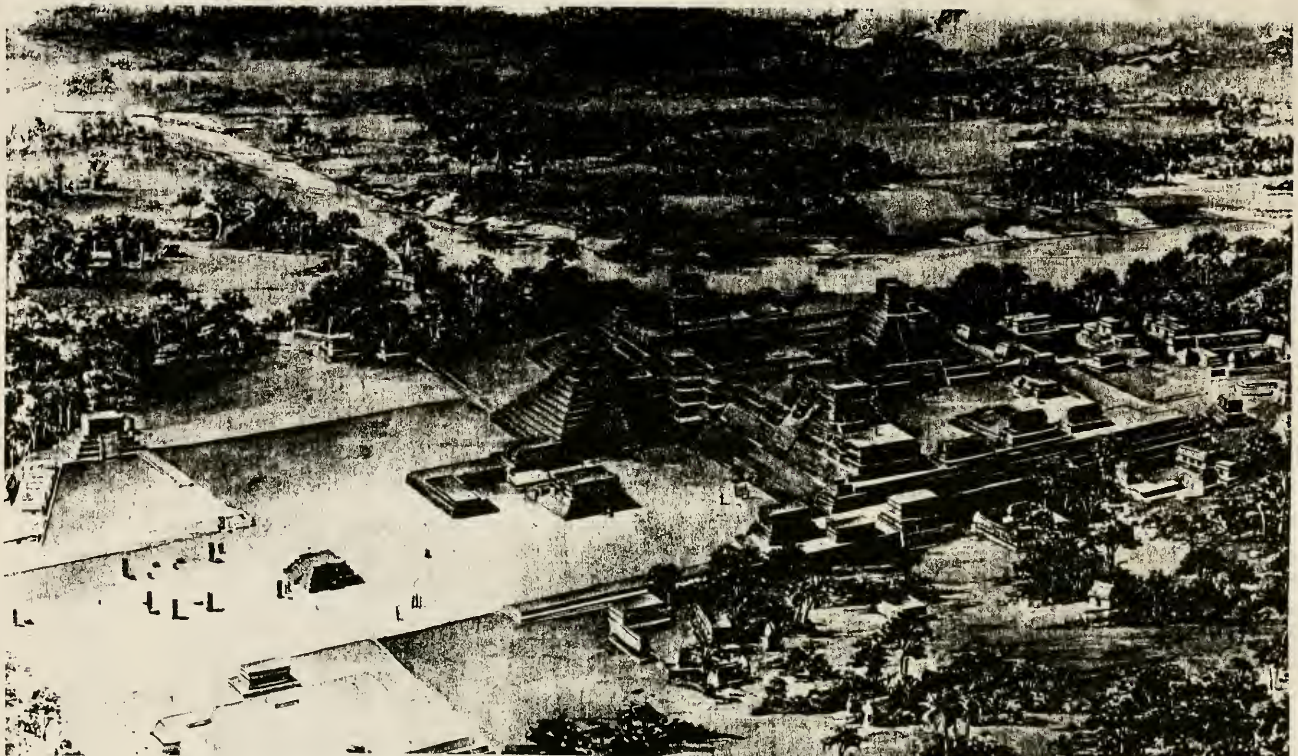

Figure 5. Reconstruction of the Principal Group of Copan. From Tatiana Proskouriakoff, *An Album of Maya Architecture*, (Norman: University of Oklahoma Press, 1963) .

Hieroglyphic Staircase, currently under excavation by Dr. William Fash and not included in this study. On the north side of the West Court is Structure 11, the Temple of the Inscriptions, which is also excluded. Hence, the corpus of data in this study represents only a portion of the Acropolis.

The "Corte" ("cut" in Spanish) is located on the eastern border, where the Copan River eroded the side of the Acropolis (Figure 6). What remains is a ten meter high archaeological cross section, known to be the largest in the world. Consequently, this stratigraphic evidence has aided in determining the relative chronology of Classic period buildings.[125]

The Acropolis stands ten meters high, built up of sequential constructions (and destructions) over four centuries. Within this period, six gross time divisions have been designated according to sequential construction phases. The final, or uppermost version of the Acropolis, is referred to as Division One; the earliest identified level belongs to Divsion Six. The final version which occupies an area of 22,500 m^2, spanning 12.5 km in length (east - west) and 2 - 4 km in width (north - south), was built in the century before the dynastic collapse (ca. A.D, 822) and has been turned into a park by the Honduran government.

In each Division, buildings were razed and new ones constructed. When a building was demolished, huge quantities of soil, stone, and plaster rubble were brought in to fill the area. After the fill was leveled off, a new plaza floor was laid to support another structure. Buildings were not always constructed directly upon preceding structures, so therefore the layout changed in each subsequent Division. Frequent repairs and additions were made which sometimes involved new floors laid directly upon old ones. In other words, it was possible for numerous floors to be constructed in one time span.

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[125] ECAP has excavated over 2.5km of tunnels from the corte to document the sequence of buried buildings which date to the time of the founding of the Copan ruling dynasty. The stratigraphy is recorded by photography, drawings, and computer-generated maps.

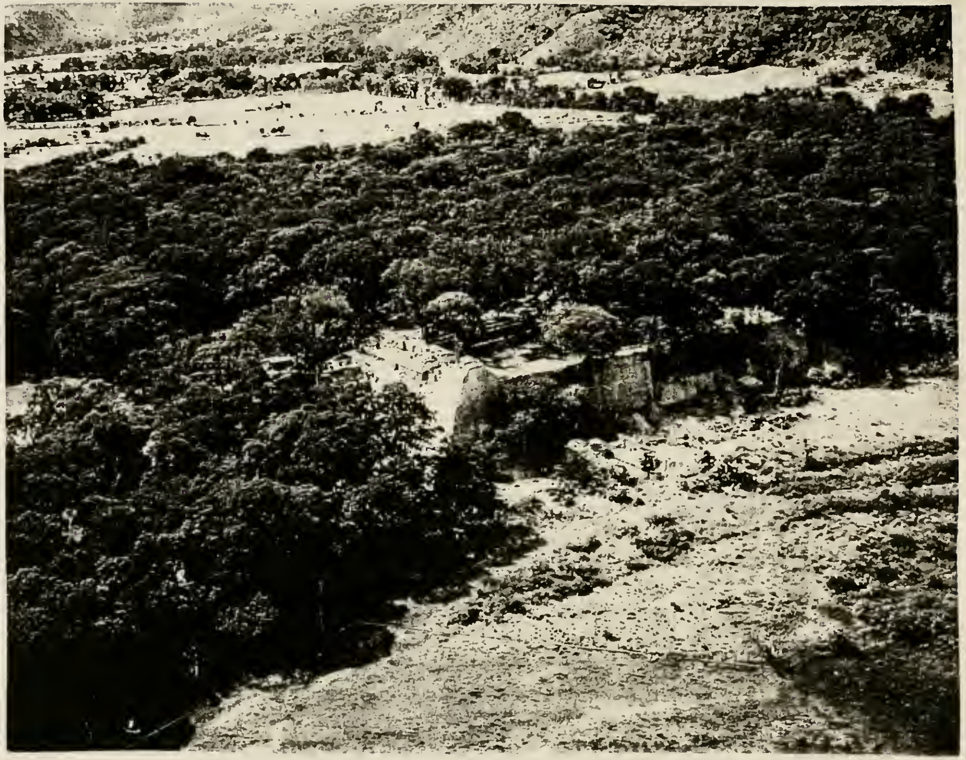

Figure 6. Corte of the eastern edge of the Copan Acropolis. From Giuseppe Orefici. *I Maya di Copan*. (Milan: Skira. 1997). 63)

Structure 16 is one exception, in that is made up of a continuous sequence of buildings (Figures 7 & 8). Two important tombs were discovered at its base which are believed to be the founding king of Copan, Yax K'uk Mo, and his wife.[126] In each subsequent version of the Acropolis, a temple was refurbished or reconstructed on the same spot, indicating a founder's temple was always constructed where Structure 16 stands.[127]

Archaeologists and researchers participating in the Early Copan Acropolis Program have established the following sequence based on absolute and relative stratigraphic dating methods in addition to interpreting the inscriptions bearing the Long Count calendrical dates.[128] Originally, the Acropolis consisted of three separate areas of development having distinct functions, entitled according to their locations: Mini Acropolis of the South (MAS), Northeast Court Group (NECG), and Structure 26 (Figure 9). MAS, the largest and most complex, began as a cluster of elaborately decorated ceremonial buildings built on elevated ground west of the Copan River; the NECG, was initially a residential development arranged around courtyards; and Structure 26 consisted of temples and ballcourts (Figure 10). MAS gradually branched out in all directions, first joining and burying NECG, which became the core of the Early Classic Acropolis. By A.D. 450, the three centers were linked by common floors and platforms. A century and a half later, they were integrated into the single elevated monumental complex that stands today.

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[126] Christine Carelli, personal correspondence, May 1996.

[127] Carelli, Ibid.

[128] To obtain accurate documentation and an understanding of the complexities of the architectural sequence a computer aided mapping program based on the COMPASS system was utilized to illustrate architectural data. Various stages of the construction sequence in this report were taken from the findings of ECAP; Sharer et al., Ibid: 6.

Figure 7. Structure 16, northeast view. From Giuseppe Orefici, *I Maya di Copan*, (Milan: Skira, 1997), 66.

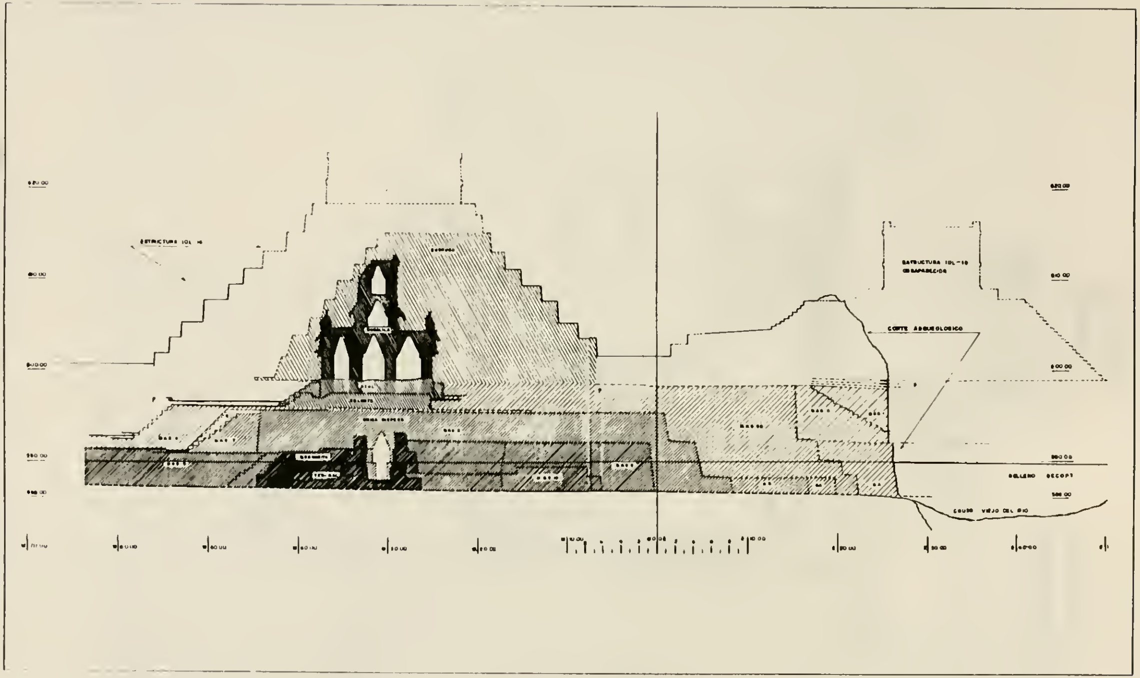

Figure 8. Preliminary Drawing of Construction Sequence of the Mini-Acropolis of the South, north-south direction. Designed by Rudy Larios based on original by Fernando Lopez, Proyecto Arcqueológico Acrópolis Cópan (PAAC), 1994.

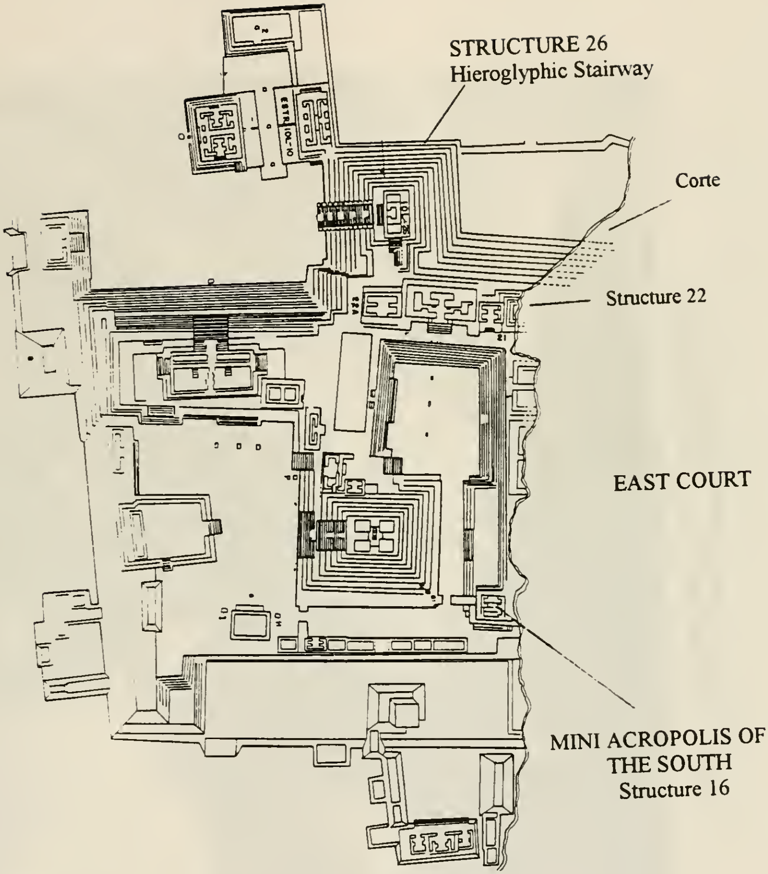

Figure 9. Early Classic Copan Acropolis. From Proyecto Arqueológico Acrópolis Copán, Instituto Hondureño de Antropología e Historia.

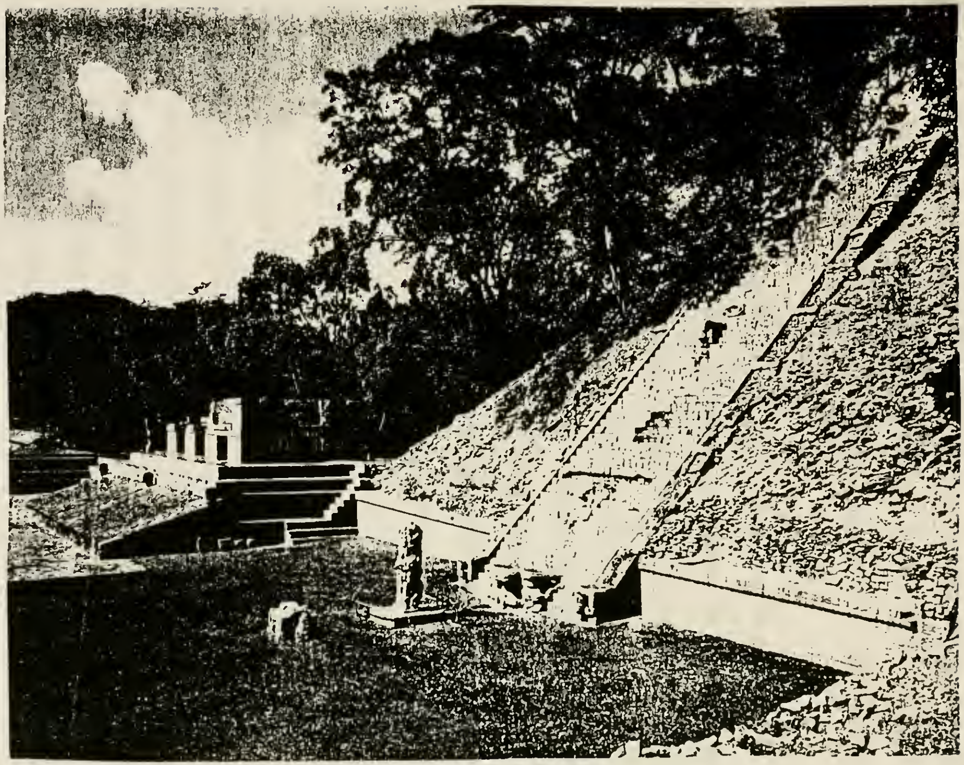

Figure 10. Hieroglyphic Stairway of Structure 26 and Ballcourt.
From Giuseppe Orefici, I Maya di Copan (Milan: Skira, 1997), 67.

The following summary of the construction sequence and evolution of the Copan Acropolis is based on the conjunctive research conducted by Robert Sharer and the participants of the ECAP program.[129]

The pre-dynastic architecture of Time Span 6, A.D. 250-400, characterized by the low, cobble-faced earthen substructures situated along the west bank of the Copan River. Modest buildings functioned primarily as residences, while the more substantial were likely used for ceremonial purposes.

Time Span 5, A.D. 420-480 (Figure 11-15), represents the period of the dynastic founding and the initiation of a major construction program in the Acropolis, involving the expansion and termination of buildings. Monumental constructions made of earth and cut stone masonry were located within the two groupings of MAS and NECG. This period witnessed the last of the cobble structures and the first appearance of a well defined plaster floor surface in the interior and exterior of buildings.

Time Span 5 is divided into seven monumental construction phases (MAS 11 - 5), each lasting about ten years. The first three stages are characterized by substructures and buildings constructed on single terraced platforms. By A.D. 450, (MAS 8; Figure 15), the complex had evolved into a two-tiered monumental platform with enough height to be considered a true Acropolis. During the following ninety years, the Acropolis expanded in height and and mass, gradually replacing adobe construction by masonry.

Noteworthy of the MAS 11 construction period (A.D. 420-430; Figure 11) is the Yehnal substructure which dates to the first dynastic ruler, Yax Ku'k Mo, representing the longest sequence of masonry architecture at Copan. Located at the heart of MAS and the entire Acropolis, it culminates with Structure 16, the highest temple of the final Acropolis configuration. The Margarita substructure, built in MAS 10 (AD 430-440), was the immediate successor to Yehnal, and the largest building of its time at Copan (Figure 11).

[129] Ibid: 11-45.

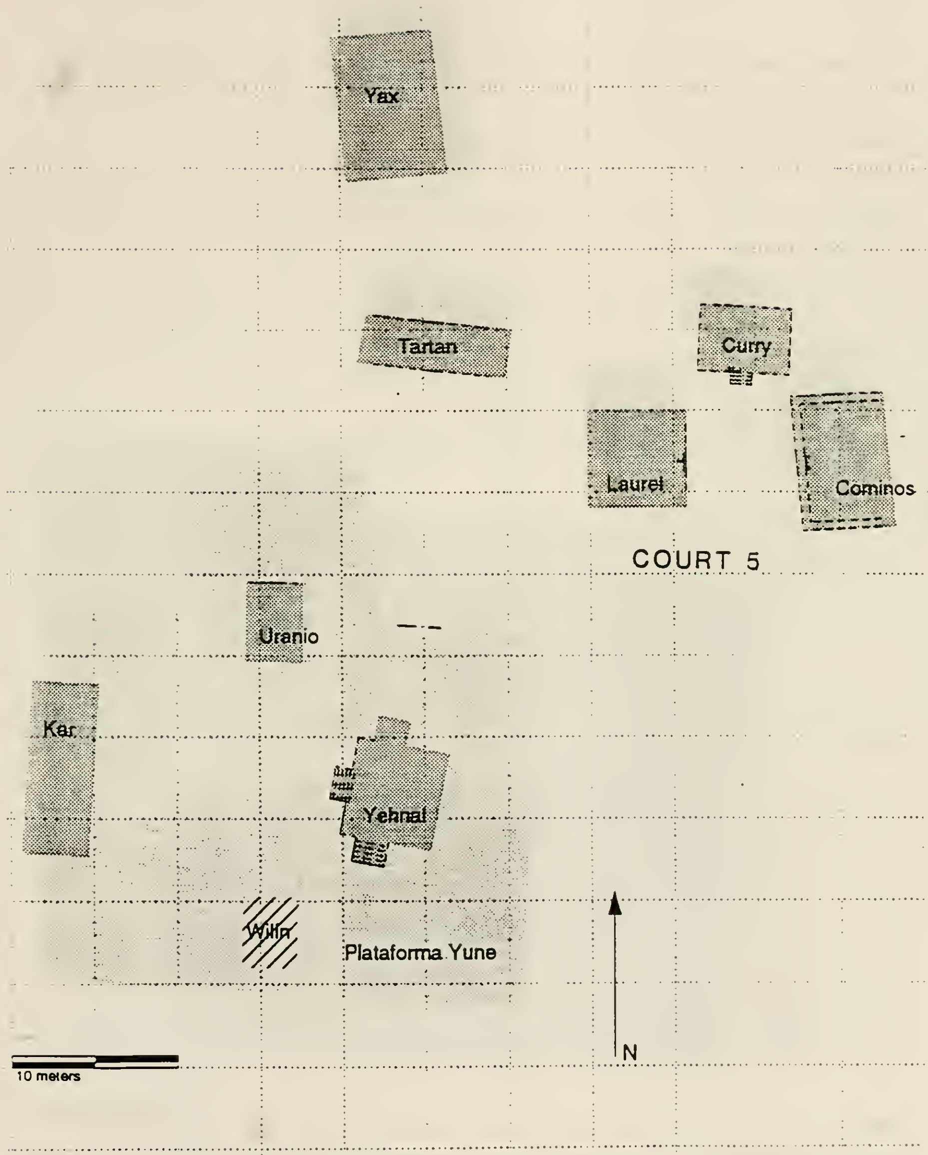

Figure 11. Preliminary Plan of Acropolis Architecture: Time Span 5, ca. AD 420-430 (MAS 11)

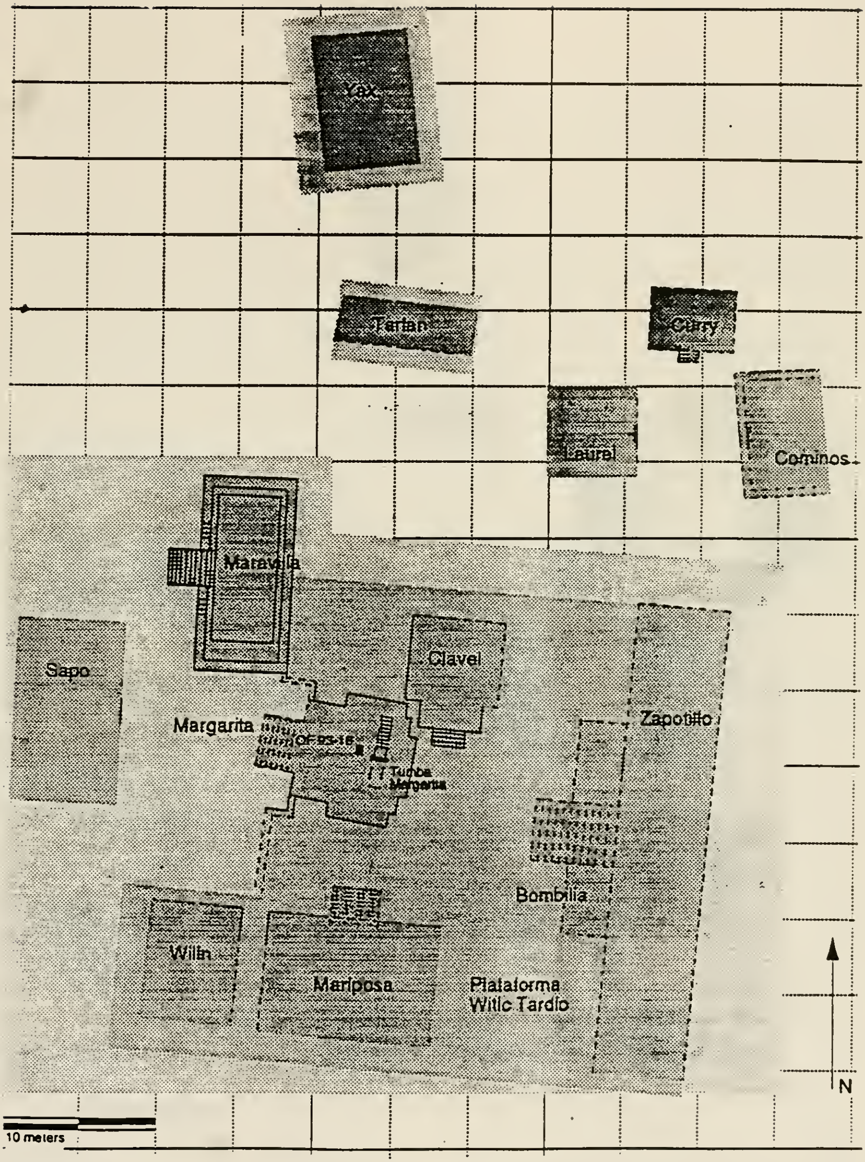

Figure 12. Preliminary Plan of Copan Acropolis Architecture: Time Span 5, ca. AD 430-440 (MAS 10A)

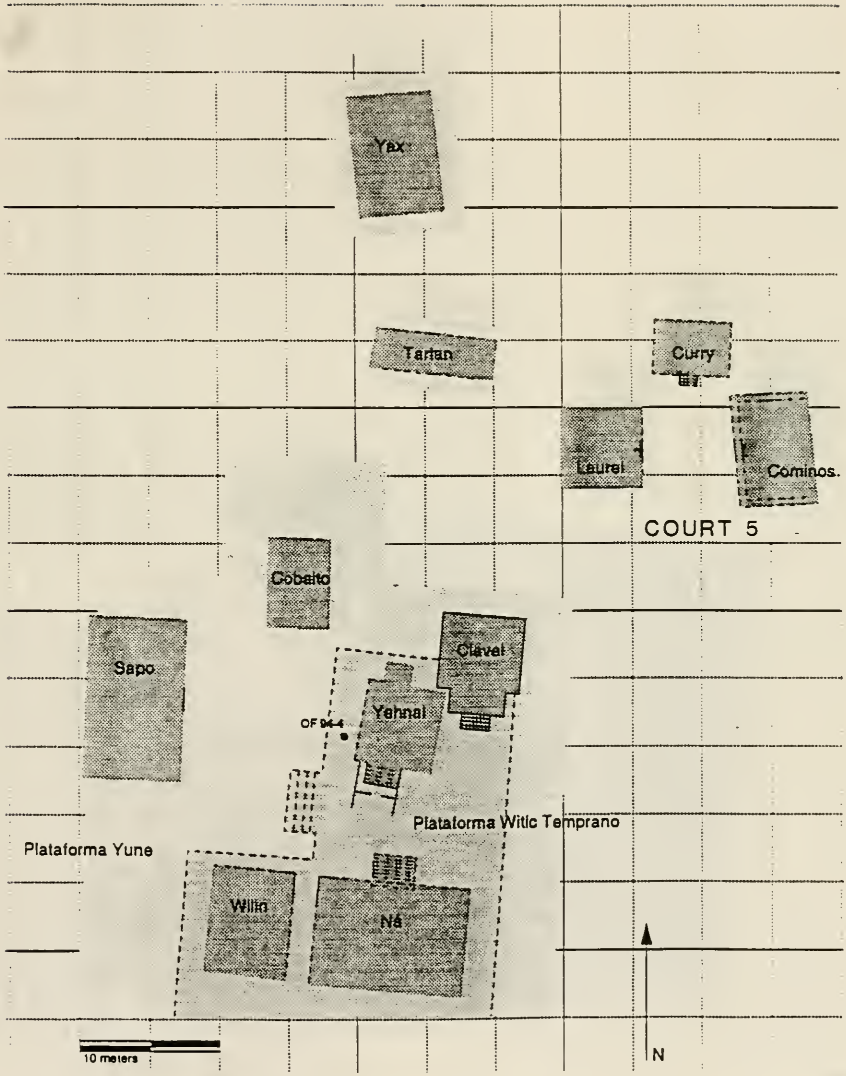

Figure 13. Preliminary Plan of Acropolis Architecture: Time Span 5, ca. AD 430-440 (MAS 10B)

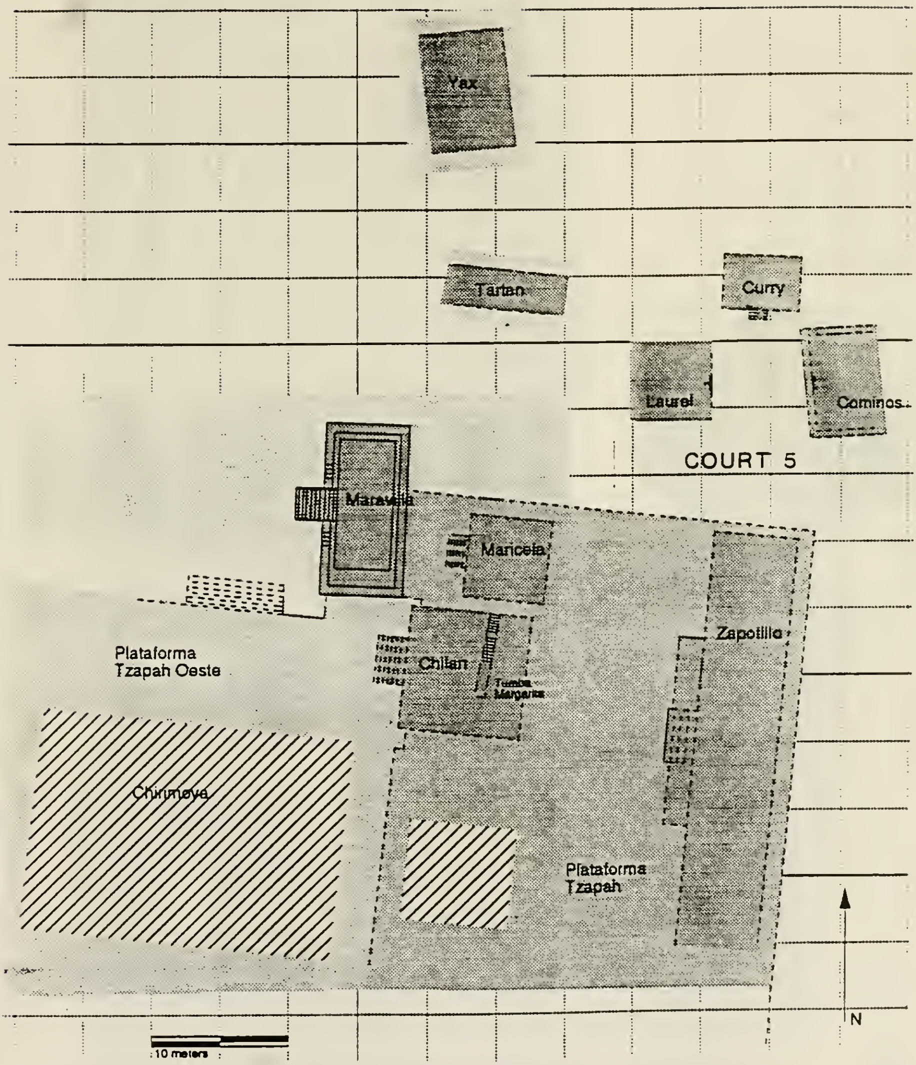

Figure 14. Preliminary Plan of Acropolis Architecture: Time Span 5, ca. AD 440-450 (MAS 9)

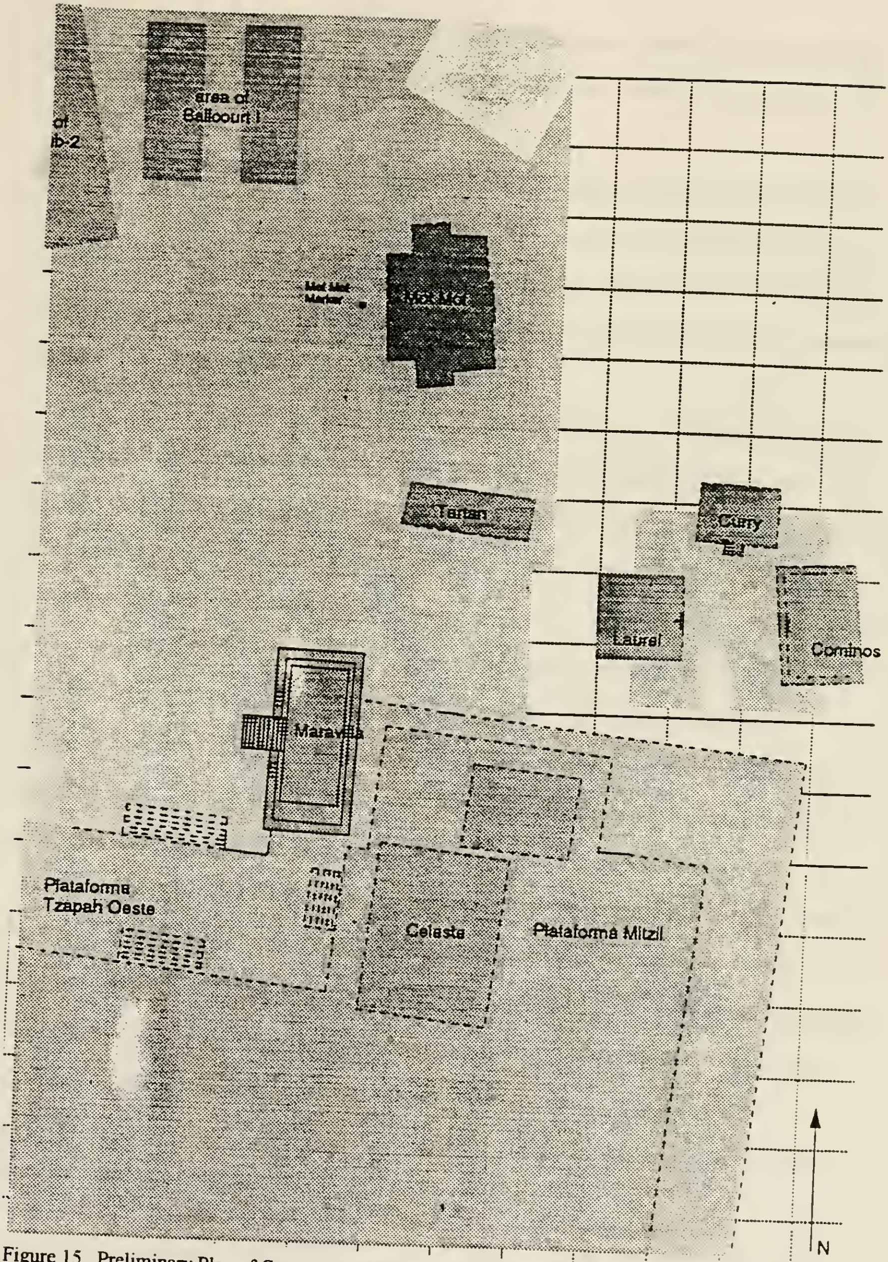

Figure 15. Preliminary Plan of Copan Acropolis Architecture: Time Span 5, ca AD 450-460 (MAS 8)

Painted red like Yehnal and elaborately decorated with stucco reliefs and hieroglyphs, its chamber contained a text indicating that Margarita held the remains of the dynastic founder.[130]

In the northern quadrant, Substructure 26 originated with a masonry constructed building known as Yax. Succeeding Yax was a larger substructure, Motmot, the floor of which is associated with Copan's earliest known ballcourt. Substructure 26 was linked to the two other groups during this period by a single, discontinuous plaster floor considered to be the first plaster floor of NECG.

During Time Span 4, A.D. 480-520, (Figure 16) the earthen architecture of Time Span 5 in the northeast area was terminated and replaced by masonry construction. An intensive construction program linked MAS and NECG by the Caimito platform, followed by the building of Court 4C, the continuous plaster surface linking all three groups, and integrating the Acropolis into a single complex.

In Time Span 3, A.D. 520-540, the Acropolis expanded northwards towards Structure 26, cancelling NECG, and initiated the construction of a new courtyard complex. The same area configuration was maintained for the next three hundred years. MAS, the highest structure in the Acropolis consisting of elaborately decorated temples, underwent its final expansion during this period.[131]

Time Span 2, A.D. 540-650 (Figure 17) reversed the original construction plan of the first century and a half established by the founding ruler. The northeast courtyard complex was terminated and possibly transferred to a new location south of the Acropolis. One of the most extraordinary buildings constructed during this period was Rosalila, the successor to Margarita, built at the sacred core of the Acropolis.[132] Unlike other buildings, Rosalila was carefully preserved before its burial. In the northeastern quadrant

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[130] Robert Sharer, *The Ancient Maya*, Ibid: 331.

[131] The destruction caused by the Copan River has erased evidence of construction.

[132] Sharer suggests its location and elaborately decorated facade including stucco masks and other motifs indicates it may have been dedicated to the dynastic founder; Sharer, *The Ancient Maya*, Ibid.

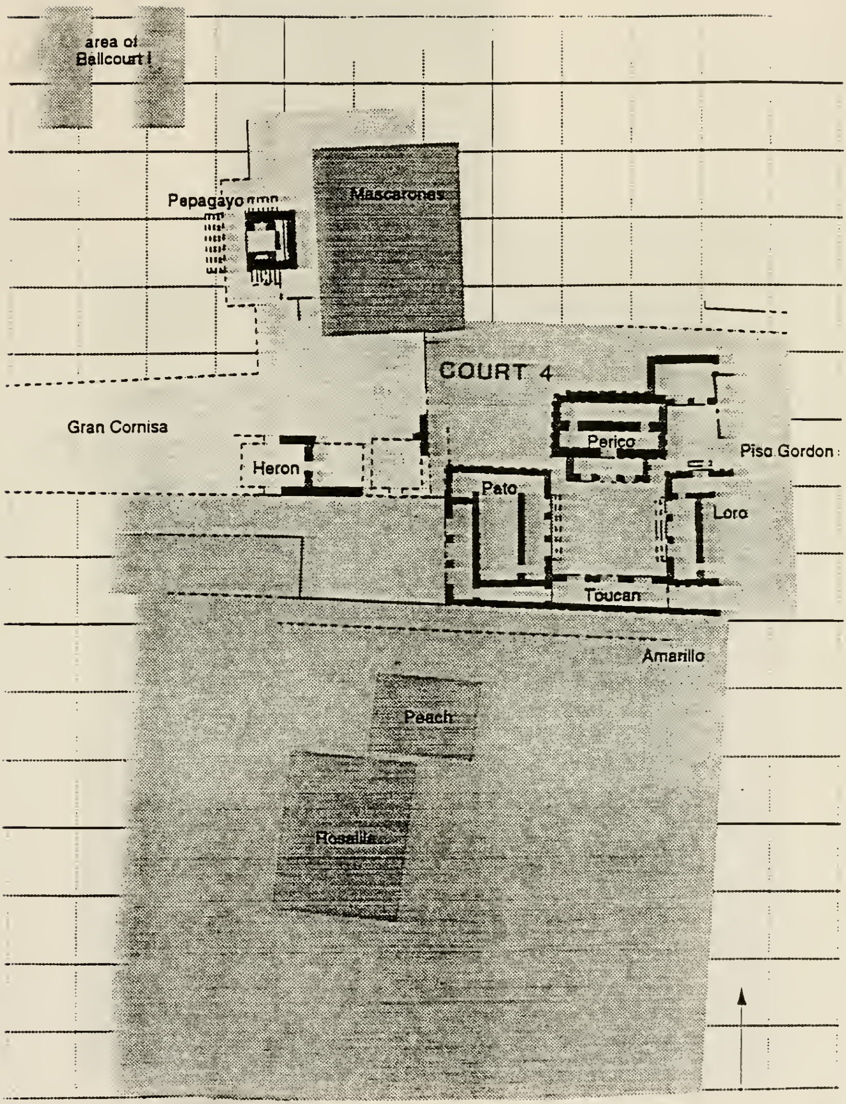

Figure 16. Preliminary Plan of Copan Acropolis Architecture: Time Span 4, ca. AD 500-520 (MAS 3)

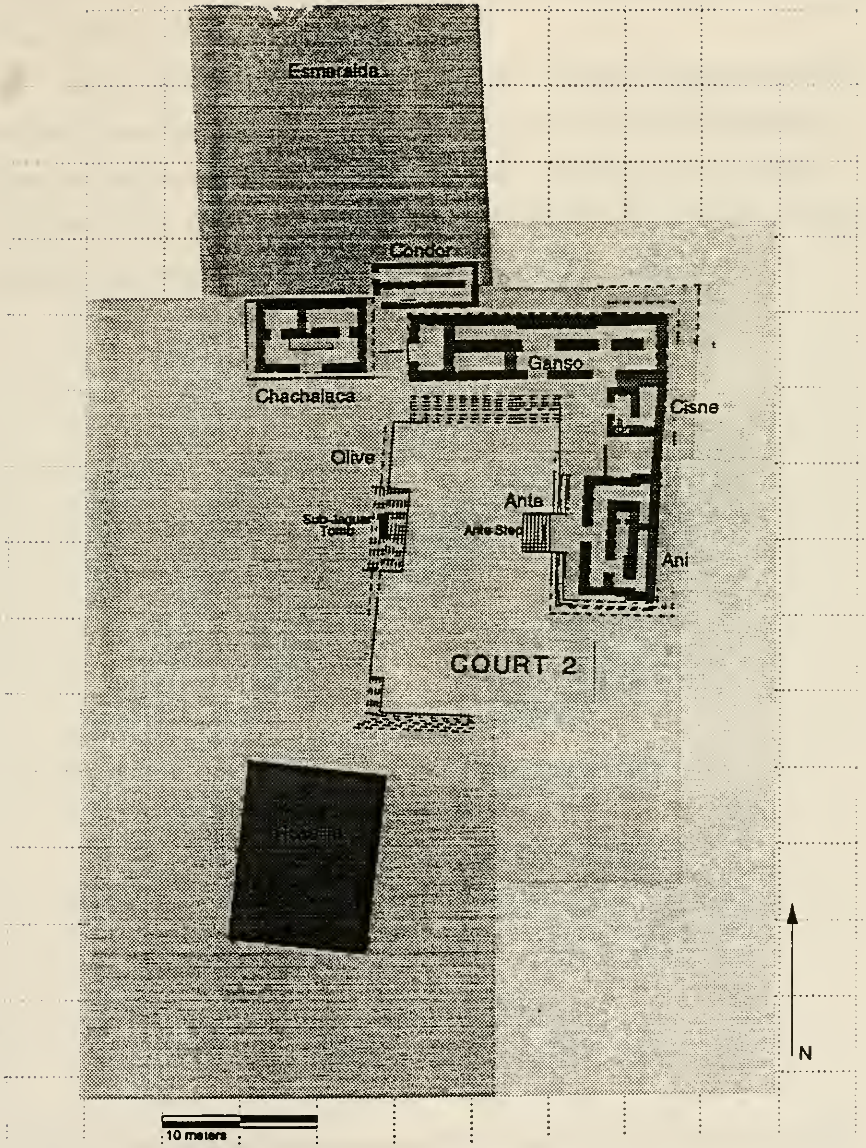

Figure 17. Preliminary Plan of Copan Acropolis Architecture: Time Span 2. ca. AD 540-650

were two venerated substructures, Indigo, and its successor Chachalaca, both elaborately decorated with mosaic masks. The two were eventually terminated and replaced by Time Span 1 buildings.

Prior to the dynastic collapse, Time Span 1, A.D. 650-822, construction developed at a much slower rate. Monumental stairways and structures were built around the East Court, including the Hieroglyphic Staircase and Structure 26 (Figure 10).[133] The final and present version of the Acropolis spans an area of approximately 22,500 m^2, 7.5 times greater than the original complex.

[133] Various buildings from this period were destroyed by the Copan River but were documented prior to their destruction.

CHAPTER FOUR
METHODOLOGY

To evaluate the Copan floor plasters in terms of their material components and processing required an investigation of their structure and composition. This was achieved by characterization and analysis. Through characterization, the physical, mechanical, and chemical properties are identified, while analysis aids in determining the constituent types and proportions and their relationships within a material.

The floor plasters used for characterization were removed from Copan in 1995 by Christine Carelli. Approximately 100 samples, (weighing approximately 35.5 grams each), were received by the Architectural Conservation Laboratory of the University of Pennsylvania (see schedule of floor samples). The 49 study samples are fragments of floor plasters, either lime or earthen (the latter was limited to just a few samples). All samples were characterized for comparative purposes and another set of plasters was chosen for further analysis because they represented a time period, significant building, or were included in a group of superimposed floors.

The study began with a review of the literature relating to the characterization and analysis of plasters. The survey provided a context for the techniques which would be appropriate to obtain information about their structure and composition.

As plasters have increasingly been recognized as materials meriting study, a methodology based on a holistic approach has been developed. A protocol for studying plasters, or any archaeological artifact, was proposed by David Kingery, which incorporates a hierarchical series of analyses in order to evaluate different structural levels.[134] Kingery's model begins with researching provenience-related documentation,

[134] David Kingery, "Microstructural Analysis As Part of A Holistic Interpretation of Ceramic Art and Archaeological Artifacts," *Archaeomaterials*, Volume 1, Number 2, Spring 1987: 2.

such as archaeological field reports and ethnohistoric accounts, supplemented by observations of the artifact's gross characteristics to reveal cultural associations. Visual examination of the macrostructure may indicate specific material inclusions and methods of production. At the microfabric level, the presence of constituents and their arrangements can be further identified. Through means of polarized light microscopy and XRD, identification of the crystal structure elucidates the presence of specific minerals. Finally, scanning electron microscopy with energy dispersive spectroscopy and differential thermal analysis definitively determine the elemental composition of a material.

The objectives of the investigation dictate the most suitable analytical techniques to implement. In archaeological research, plaster investigations have been undertaken to resolve issues related to provenience, dating, and cultural associations. Some levels are omitted if they are irrelevant to the questions posed for the investigation. Satisfactory characterization often can be achieved with relatively inexpensive and sample size dependent techniques, and if necessary, enhanced by selective instrumental analysis.[135]

Research began with a survey of archaeological field reports, geologic studies and previous investigations related to the nature of lime plasters. Archaeological field reports, furnished by Robert Sharer, provided a historical background and chronological context of the Acropolis from which the floor plasters were retrieved. Field notes provided by archaeologist, Christine Carelli, were reviewed to inform sample location within the site and to establish a relative chronology.[136] Regional geologic studies performed by Gail Mahood provided a context for the available resources which may have been exploited for the manufacture of plasters.[137]

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[135] Gordon Brown, *The Analysis and History of Cements*, Ibid: 77.
[136] Field notes were provided by Christine Carelli who removed representative floor plaster samples from the Acropolis, March 13-16, 1995.
[137] Gail Mahood et al., "Habitat y Agricultura en la Region de Copan" Ibid: 42-66.

Bulk sample examination was performed to glean basic compositional information of the samples and to identify evidence of manufacturing processes. Properties such as color and hardness were also noted.

Reflected and transmitted polarized light microscopy were used to gain a general understanding of the structure and composition of plasters. Cross sections and thin sections prepared from the samples were characterized to ascertain the presence and ratio of components and their microstructure. Using cross sections, features such as stratigraphy, color, and texture were identified. Thin sections provided information on the microfabric, the component parts and crystalline phases of inorganic materials that are only discernible at higher magnifications. Viewed under transmitted polarized light, a thin section of a sample reveals the mineralogical composition and the relationship between constituent materials. The identification of features such as grain size, mineral impurities and textural characteristics aids in evaluating the materials used and possible manufacturing techniques.[138] Because thin sections reveal not only the macro and microstructure of components but their interrelationships, it is often more useful in plaster investigations than other analytical techniques such as scanning electron microscopy, x-ray diffraction and elemental analysis.[139] Observations related to the mixing, grading and proportioning of aggregates were evident at this level and allowed general conclusions regarding the care and technical skill involved in the manufacturing of such materials.

Scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS) was employed to identify the elemental composition of materials and observe the microstructure at higher magnifications. Advantages of this analysis include a large depth

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[138] According to Scholle, some of the most useful petrographic work has resulted from studies of quartz grain variations. Since quartz is the most ubiquitous material in sediments, it is perceived as a source indicator and its features such as texture, size, shape, and inclusions have been used in provenance research; P.A. Scholle, *A Color Illustrated Guide to Constitutents, Textures, Cements, and Porosities of Sandstones and Associated Rocks*, Tulsa, American Association of Petroleum Geologists, 1979.

[139] Chandra L. Reedy, "Thin Section Petrography in Studies of Cultural Materials," *Journal of the American Institute for Conservation* 33, No. 2, Summer 1994: 123-124.

of focus, higher resolution, and qualitative elemental analysis of both crystalline and non-crystalline phases. At the molecular level, x-ray diffraction was effective in determining the clay minerals and inorganic crystalline compounds present in plasters.

Wet chemical analysis was implemented in order to qualitatively identify the acid-soluble and insoluble matrix fractions of the samples. The remaining acid-insoluble fraction was sieved to obtain particle size distribution. In addition, information was provided about the types, sizes, and shapes of aggregates which play a critical role in the behavior and durability of plasters.

4.1 SAMPLE PREPARATION AND EXPERIMENTAL PROCEDURE

Bulk Sample Examination: Samples were examined by various techniques to qualitatively describe their gross physical characteristics. All samples were examined in bulk under daylight with the unaided eye and under low power magnification using a Nikon SMZ-U stereomicroscope to identify their macrostructure and any distinguishing features. Optical properties, such as the color and texture of different components, and evidence of any inclusions were noted.

Color: The Munsell system is a means of objectively describing color using three criteria: hue, value, and chroma. Hue (H) specifies principle colors (red=R, yellow=, etc), value indicates lightness or darkness, and chroma (C) indicates purity or grayness. Colors are recorded with a system of numbers and letters as H V/C. Dry bulk samples and wet fines were evaluated for color using the Munsell Color System by comparing them with standard color chips in the Munsell Soil Color Chart.[140]

[140] *Munsell Soil Color Charts*, Baltimore: Macbeth Division of Kollmorgen Instruments Corporation, 1988.

Hardness[141]**:** A simple hardness test was performed to obtain data on the relative strength of the floor plasters.[142] The resistance that a surface of a mineral yields to scratching is its hardness, determined by observing the comparative ease or difficulty with which one mineral is scratched by another.[143] The following minerals, arranged in order of increasing hardness, comprise what is known as the Moh's scale of hardness:

1. Talc	6. Orthoclase
2. Gypsum	7. Quartz
3. Calcite	8. Topaz
4. Fluorite	9. Corundum
5. Apatite	10. Diamond

Although developed for geological uses, the Moh's Hardness Test allows a relative comparison of abrasion resistance for each plaster, measuring "friability." Since none of the plasters had a hardness value greater than calcite (3), the first three minerals were used for comparative purposes. The measurement was always applied on a newly cut or broken surface as that which has been exposed would be harder than its interior and would therefore indicate a deceptively higher strength.[144]

Cross Section Examination: Examination of the plaster samples began with reflected light stereo microscopy. A portion of each sample was embedded in Bioplast™, a commercial polyester/methacrylate resin polymerized with a methyl ethyl ketone peroxide catalyst, and cured under a tungsten lamp. The solidified samples were sectioned with a Buehler Isomet™ low speed saw and polished with 400 and 600 grit abrasive paper and a felt cloth. The embedded, polished cross sections were examined in normal reflected

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[141] According to Frank Matero, this is not a good test for composites such as plasters. In addition, abrasion resistance of plasters would depend on surface hardening from cure migration of colloidal lime particles and soluble calcium carbonate.

[142] Some samples were excluded because they were not of a sufficient size. In addition, testing for compressive strength was not possible for the same reason. While admittedly it is a subjective test, it has relative value for comparing samples within the same time span.

[143] The evaluation of hardness is determined by the reaction of a crystal structure to stress without rupture; Cornelis Klein and Cornelius S. Hurlbut, Jr., *Manual of Mineralogy*, New York, John Wiley and Sons, 1989: 254.

[144] Gordon Brown, *Analyses and History of Cement*, Ibid: 8.

quartz-halogen light using a Nikon SMZ-U variable magnification stereo microscope and a Nikon Optiphot 2. Basic observations were recorded, such as color, layers, texture, inclusion, and unusual features.

Thin Section Examination: Of the study plasters, six floor samples were selected for further investigation.[145] The representative samples were sent to a commerical petrographic laboratory for thin section preparation.[146] Standard size thin sections were prepared from two earthen plasters and four lime plasters. All of the thin sections were stained on one side with alizarin red S to distinguish the calcium carbonate content.

The thin sections were examined in plain and cross polarized light using a Zeiss MC100 Axioplot Polarizing Microscope and a Nikon Optiphot 2-Pol Polarizing Microscope at 25x to 100x magnification.[147] Micromorphological features of the samples were noted such as the abundance of particles of various sizes, degree of sorting, particle shape, porosity, surface texture, and related distribution.[148]

Scanning Electron Microscopy with Energy Dispersive Spectroscopy: Scanning electron microscopy (SEM) was used in order to examine and characterize the plasters in terms of their constituents, patterns of distribution of phases in the matrix, composition, morphology and sizes. Used in conjunction with the Energy Dispersive X-ray Analyzer, the relative quantity, morphology and elemental composition of the constituents was obtained.

Five representative cross sections were analyzed with a JEOL 6400 scanning electron microscope and mapped with the EDS for a more complete assessment of the constituents and their arrangement.[149] The samples were polished using 240, 400, 600,

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[145] The selection was based on Christine Carelli's recommendation.
[146] The thin sections were prepared by San Diego Petrographics, Escondido, CA.
[147] Professor Gomaa Omar of the Department of Geology, University of Pennsylvania generously provided his time, expertise, and advice in the examination and interpretation of the thin sections.
[148] P. Bullock, et al, *Handbook for Soil Thin Section Description*, Albrighton, Wolverhampton, 1985: 9-38.
[149] SEM examination was performed in the Laboratory for Research on the Structure of Matter, University of Pennsylvania with the assistance of Xue-Qin Wang.

and 1200 grade polishing paper, then coated with carbon or gold to provide a conductive surface and prevent electrostatic charging. Each sample was viewed at various magnifications and energy dispersive spectra were obtained. For one sample, x-ray dot mapping was used to determine the presence or absence of particular elements in the matrix.

Wet Chemical Analysis: To identify both qualitatively and quantitatively the presence of acid-soluble and insoluble material, wet chemical analysis was employed. Analysis of the binder (typically calcium carbonate ($CaC0_3$), soluble in acid), aggregate or sand, and fines (fine-sized impurities such as clay), was critical to understanding the nature of the plasters and their relative.

A simple procedure used to determine the proportions of the plaster components was to digest a pre-weighed and ground sample with 15% (v/v) hydrochloric acid (HCl).[150] The material lost during the process as carbon dioxide and gaseous water was equivalent to the carbonate or soluble silicate fraction. The remaining insoluble fraction was washed several times and left for 24 hours to dry before weighing. The amount of carbonates and sand was recorded as a w/w percentage of the whole sample before and after acid-washing.

Particle Size Distribution: To determine if patterns existed in the gradient as a function of time and/or location, the size distribution of aggregates was examined. The acid-insoluble sand obtained from the gravimetric analysis were sieved in seven sieves of decreasing sizes. The sand collected from each sieve size was weighed and their respective proportions were calculated as part of the total weight of the sand.

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[150] Jeanne Marie Teutonico, *A Laboratory Manual for Architectural Conservators* , Rome: ICCROM, 1988, 112-115.

X-Ray Diffraction: The coarse fraction from three samples was analyzed by using XRD.[151] XRD is an analytical technique by which data about the compound species in a material is obtained. The technique is based on the fact that wavelengths of x-rays are almost identical to the internal spacing of atomic particles within crystals. When x-rays pass through a crystalline material, they diffract, producing a characteristic spectra.[152] This spectograph is compared with the spectra of known samples to estimate the relative abundance of the minerals present in the sample over 10%.

High Performance Liquid Chromatography: HPLC is an analytical technique by which complex mixtures of related organic compounds may be separated. In order to determine the possible inclusion of bark extracts in the Copan floor plasters, HPLC was performed on one sample (#59).[153] This sample was a likely choice since it exhibited a strong red color which may have resulted from the addition of tannic.

HPLC instruments consist of a reservoir of a mobile phase, a pump, an injector, a separation column and a detector. A sample is injected into the column whereby different components in the mixture pass through the column at different rates due to differences in their partitioning behavior between the mobile liquid phase and the stationary phase. The relative distances the various substances have travelled are compared to movements of known substances under same conditions.

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[151] X-ray diffraction was conducted at the Laboratory for the Research of the Study of Matter. Interpretation of the samples was assisted by George Austin of the New Mexico Bureau of Mines. Three plasters were not analyzed since they did not contain sufficient sample material.

[152] Duane M. Moore and Robert C. Reynolds, Jr., *X-Ray Diffraction and the Identification and Analysis of Clay Minerals*, Oxford: University Press, 1989: 13.

[153] High Performance Liquid Chromatography was performed at the University of Pennsylvania MASCA, by Donald Glusker. Testing was limited to one sample.

4.2 EXPERIMENTAL RESULTS

4.2.1 Bulk Sample Examination

Preliminary examination revealed a variety of sizes ranging approximately from 1/2" to 3." The bulk samples varied from small subrounded lime covered pebbles to larger fragments. Plasters were predominantly white in color with slight variations of tan, gray, and pink. Upon closer examination, many samples were observed to consist of fine to coarse grained particles and covered with a fine-grained dust of white, reddish tan or tan particles. Several plasters revealed aggregate inclusions of various colors and a few exhibited fine-sized silvery particles. At the macroscopic level, no strata were discernible. The plaster matrices appeared rather compact due to the predominance of the fine-grained cement.

4.2.2 Color

The majority of bulk samples display varying shades of white due to the high content of calcareous material. Several samples exhibit light shades of gray, pink, and brown attributed to the presence of mineral impurities or aggregate inclusions. This color variation is more pronounced in earlier samples consisting of a mixture of lime and earthen plasters. Division 2 samples, particularly from Rosalila, exhibit a greater similiarity in color, primarily in white and pinkish-white.

Any evidence of a painted surface such as the use of red for example, as noted in ethnographic accounts, was pursued. However, to the unaided eye, none of the plaster samples confirmed this possibility.

A greater diversity in color was observed in the fine fraction. The majority of samples from all construction phases were brown or variations thereof, such as red-brown,

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A greater diversity in color was observed in the fine fraction. The majority of samples from all construction phases were brown or variations thereof, such as red-brown,

yellow-brown, gray-brown, or pale-brown. In general, each color was observed in at least three time spans which may indicate different sources were used within each division.

In Division 6, the fine fraction colors are red-brown and gray-brown. Division 5 plaster fines include brown, red-brown, yellow-brown, gray-brown, and pale-brown colors, which are not location-specific. Division 4 fines exhibit brown and yellow-brown colors. The fines from Division 2 include the colors observed in the preceding divisions, with the addition of red-yellow, pink, and pink-gray colors, which are also not location or building-specific.

4.2.3 Hardness

Tests indicated that within each time span the hardness of the plaster samples widely varied, displaying measurements ranging from 1/2 to 3". Among the various construction phases, Division 5 plasters exhibited the greatest consistency. The majority fell within the range of 2 - 2 ½, and the minority between 1/2 and 3. Throughout all time spans, it was observed that few superimposed samples shared the same hardness measurement, suggesting the quality of lime varied with every mixture.

Bulk Sample Examination		
Sample	Moh's Hardness	Sample Description
Division 6		
37	*	White fine-grained particles with dark micaceous particles.
101	1	White chalky substrate with tan fine-grained particles, well compacted.
Division 5		
36	*	Mostly pebbles covered by thin layer of brownish-gray fine sized particles.
83	2	Gray-tan matrix with darker particles, fine grain, gray particles in pockets, well compacted.
84	2 ½	Small tan and white pebbles with chalky patches covered with particle dust, well compacted.
95	2 ½	Gray and white substrate with fine grained brown and peach particles.
96	2	Pinkish white with fine tan particles, chalky patches, visible aggregates
97	2 ½	Light tan with fine orange and gray particles, well compacted, pebble-sizes.
98	1	Reddish-tan with gray areas, rust colored particles in pockets, well compacted
99	2 ½	Tan and gray with fine gray particles, dark gray aggregates visible, chalky patches, well compacted.
82	*	Tan colored with fine white particles, chalky patches, multi-colored aggs.
107	2	Tan, fine particle matrix with coarse chunks of lime, multi-colored aggs.
105	3	Tan and white with brown fine particle patches, gray aggregates
27	*	Fine and coarse grained white sandy particles, chalky surface
26	½	Chalky surface with peach, white, and tan fine particles, dark patches
38	1	White pale brown with peach, yellow and gray fine particles, compacted
81	2 ½	Pinkish white matrix covered with white, tan, and peach particles. Several small lightly dusted pebbles
80	½	Fine brown particles with chalky patches, friable.
88	3	Gray and tan, uniform color, chalky white patches, peach fine-grained dust, well compacted.
89	½	Light gray, mostly pebbles and dust, fine particles, grayish tan uniform color, multi-colored aggregates visible, friable.
90	*	Pebble sizes, gray and coral colored aggregates, friable.
Division 4		
28	½	White substrate, reddish-tan and pink fine particle covering.
34	*	Yellowish-white uniform color, fine grained particles covering pebble size shapes, friable.
35	½	Chalky patches, gray and tan fine particles, small aggregates visible, friable.
58	2 1/2	Pinkish white, fine-grained particles, chalky patches, well compacted.

* Insufficient sample size for testing.

Bulk Sample Examination		
Sample	Moh's Hardness	Sample Description
Division 2		
67	2 ½	Brownish tan with white, pinkish, and gray fine particle dust, friable.
40	2 ½	Tan and pink with fine black particles, chalky patches, well compacted.
53	2 ½	White-pale brown, smooth surface light reddish-tan, rust and gray fine particles.
54	*	Pinkish white smooth surface covered with light tan fine particles, friable.
64	½	White and light gray covered with fine tan particles, crack in the middle, few black particles visible.
63	2	Pinkish gray with chalky patches, black gray aggregates visible, well compacted.
62	*	Small pebble sizes of white and gray covered with fine reddish-tan particles, chalky patches.
61	2 ½	Pinkish white with chalky patches, fine grained particle dust.
60	*	Tan and peach fine-grained particles, gray aggregates visible.
59	*	Fine-grained peach particles with white aggregates.
65	3	Peach and tan fine particles, chalky patches, visible aggregates, well compacted.
70	1	Pinkish white uniform color covered with fine grained particles, chalky patches, friable.
71	3	Yellowish white, fine particle dust covering visible aggregates below surface.
72	2	Yellowish tan uniform color, fine grained particles, chalky white substrate.
77	1	Gray, pink and green aggregates, shalky patches, well compacted.
28020	*	Light tan particles, uniform color, chalky patches, friable.
28021	1	Reddish-tan and gray fine particles, mostly pebble sizes, friable.
27306	3	Reddish-tan and white, chalky patches.
26733-1	1	Gray and tan fine particles, compact.
26733-2		Yellow, pink-white matrix, chalky patches, visible aggregates, friable.
27304	1	Fine-grained particles, few visible aggregates, uniform color, friable.
26677	2	Large tan, pink, and gray chunks covered with fine tan particles.
26724	2 ½	Pale brown covered with fine grained particles, reddish-tan with chalky patches.
26719	1	White, gray and pink fine grained powder, few black gray aggregates.
25150	½	Well compacted, smooth surface, fine particle dust covering, pink-white uniform color, friable.
26701	1 ½	Gray covered with fine-grained white particles, visible aggregates.
26725	2 ½ -	Grayish white substrate covered with fine peach particles, visible aggregates, well compacted.
28024	2	Tan and pink fine particle dust, uniform color, visible aggregates.

* Insufficient sample size for testing.

Munsell Colors				
SAMPLE	Dry Bulk Sample Color		Wet Fines Color	
Division 6				
37	5YR 5/1	gray	10YR 6/2	light brown gray
101	10YR 7.8/1.3	light gray	10YR 5.5/3	brown
Division 5				
36	5YR 5/4	reddish brown	10YR 6/2	light brown gray
83	5YR 7/2.5	pinkish gray	5YR 4.5/4	reddish brown
84	5YR 8/1.3	pinkish white	10YR 3.5/2	dark grayish brown
95	5YR 8/1.7	white	10YR 5/3	brown
96	5YR 8/1.5	pinkish white	10YR 7/3.5	very pale brown
97	5 YR 8/1.5	white	10YR 3/3	dark brown
98	5YR 7.5/2.5	light gray-pinkish white	5YR 3.5/2.5	dark reddish brown
99	10YR 8/1.5	white	10YR 6/2	light brownish gray
82	5YR 7.8/1.3	pinkish white	7.5YR 5.5/4	brown
107	5YR 7.8/1.8	light gray	5YR 5.5/2.5	light reddish brown
105	5YR 8/1.4	white	7.5YR 4.5/4	brown
27	5YR 7.5/1	pink	5YR 5/2.5	reddish gray brown
26	5YR 7.8/1.7	pinkish white	5YR 4/4	reddish brown
38	10YR 8/2.3	white-pale brown	10YR 5/4	yellowish brown
81	5YR 8/1.5	pinkish white	5YR 5/3.5	reddish brown
80	10YR 8/1.4	white	10YR 6/3.5	pale brown-light yellowish brown
88	5YR 8/1.5	pinkish white	10YR 6/4	light reddish brown
89	10YR 8/1.5	light gray	10YR 4.5/3	brown
90	10YR 8/1.8	white	5YR 3.5/3	dark reddish brown

Munsell Colors				
SAMPLE	Dry Bulk Sample Color		Wet Fines Color	
Division 4				
28	5YR 8/1.7	pinkish white	10YR 3/4	dark yellowish brown
34	10YR 8/1.7	white	7.5 YR 4.5/5	strong brown
35	10YR 8/1.3	white	10YR 7/3	very pale brown
58	10YR 8/1.5	white-pinkish white	7.5 YR 5/3	Brown
Division 2				
67	10YR 6.8/1.3	light gray	10YR 6/2	light brownish gray
40	5YR 8/1.7	white	5YR 6/7	reddish yellow
53	10YR 8/2.3	white-pale brown	10YR 5/4	yellowish brown
54	7.5 YR 7.8/1.8	pinkish white	10YR 7/4	very pale brown
64	5YR 7/5/1.5	pinkish white	5YR 6/3	light reddish brown
63	5 YR 7.8/1.5	pinkish white	10YR 7/4	very pale brown
62	5YR 7.5/2	pinkish gray	7/2.5	pale brown
61	10YR 7.8/2.5	pinkish white	10YR 7/2.5	light gray-very pale brown
60	5YR 8/1.8	pinkish white	10YR 6/3	pale brown
59	7.5 YR 8/2	pinkish white	10YR 7/4	very pale brown
65	5YR 8/3.5	pink	5YR 7.5/3	pink
70	10YR 8/1.8	white	10YR 6/3.5	pale brown
71	10YR 8/1.8	white	10YR 6/3.5	pale brown
72	10YR 8/1.8	white	10YR 8/2.5	very pale brown
77	10YR 8/1.8	white	7.5YR 5/5	brown

Munsell Colors				
SAMPLE	Dry Bulk Sample Color		Wet Fines Color	
Division 2 Rosalila				
28020	5YR 8/1	white	10YR 6/4	light yellowish brown
28021	5YR 7.8 1/5	white	10YR 5/2	grayish brown
27306	10YR 8/17	white	10YR 6/4	light yellowish brown
26733-1	5YR 8/1	white	5YR 5/4	reddish brown
26733-2	10YR 8/1.5	white	10YR 6/5	brownish yellow
27304	10YR 8/1.5	white	10YR 4/3	Brown
26677	5YR 8/2	pinkish white	10YR 5/2	grayish brown
26724	10YR 8/2.3	white-very pale brown	10YR 7/4	very pale brown
26719	10YR 8/1.7	white	10YR 6/3	pale brown
25150	5YR 8/1.8	pinkish white	10YR 5.5/4	pale yellow-brown
26701	5YR 8/1.4	white	10YR 6/3	pale brown
26725	10YR 8/1.5	white	10YR 4/4	dark yellowish brown
28024	10YR 8/1.5	pinkish white	10YR 7/4	very pale brown

4.2.4 Cross Section Summary

The floor plasters viewed in cross section varied microscopically in texture, aggregate types and sizes, and did not exhibit a discernible evolution in structure and composition over the four hundred year span.[154] As observed in previous analyses, the Copan floor plasters consisted of fine calcite particles, quartz and feldspars, and occasionally shell fragments bound in a lime matrix.[155] Despite the varying proportions of aggregates, a common feature throughout all divisions was the presence of calcite particles, indicating limestone fragments or sascab, in subrounded and subangular shapes, which were distinct from the background of precipitated cryptocrystalline or microcrystalline calcite cement. They were visible in greater proportions than siliceous aggregates, implying they were included as aggregates to serve as a bulking agent.

Calcite particles observed within each cross section, provided a rough approximation of their proportions. Again, there was considerable diversity within each division and throughout successive construction phases. In Division 6, 30 - 50% of the sample was dominated by calcareous particles. Division 5 plasters contained calcite-based aggregates which ranged from 0% to 80%, though several samples contained an average of 60%. Calcareous particles found in samples from Division 4, ranged from 10% to 50%. Division 2 plasters consisted of 0% - 80% calcite-based particles, though many samples averaged between 40% - 50%.

Division 6: Samples were represented by two plasters: an earthen plaster (#37) and lime plaster (#101) from later in the sequence. The earthen plaster contained a greater proportion of coarse-sized aggregates and a rather unusual constituent, a rock, measuring approximately 3.0 mm, displaying incised marks (Figure 18). Both samples contained volcanic tuff and aggregates in angular, subangular and subrounded shapes. The majority

[154] Since the presence of individual layers is rare, textural qualities are critical in discerning modes of production.
[155] Hyman, "Pre-Columbian Cements," Ibid: A84 – A86.

of aggregates in the lime plaster (#101) were calcite-based, representing limestone fragments, followed by fine-sized quartz sand particles.

Division 5: Samples did not exhibit a discernible progression in structure or composition throughout successive constructions, or a synchronic consistency within specific locations. For example, all three areas, MAS, the Northeast Court Group, and Structure 26, contained plasters with either smooth or chaotic textures and variations in aggregate types, sizes and shapes within the same construction phase.

The majority of samples exhibited heterogeneous textures with calcareous particles in various sizes, of mostly rounded and subrounded shapes. They may represent limestone aggregates or calcareous material not calcined to the same degree as the surrounding matrix. The calcareous fraction, found to constitute 80 - 90% of the plaster's weight, evidences their function as aggregates. Moreover, calcareous particles were in considerably greater proportion than their siliceous counterparts which further supports this.

The acid-insoluble aggregates varied in type, size and shape, strongly suggesting they were collected from different sources. Most aggregates were represented by a combination of quartz sand and tuff particles ranging from fine to coarse sizes. On the other hand, the earliest lime plaster (#83) contained only volcanic tuff aggregates; this characteristic did not appear again until Division 2.

The structure and composition of the plasters were very diverse. The earliest sample in the sequence, an earthen plaster (#36), contained primarily coarse-sized and rounded aggregates, a neglible amount of calcareous material, and lacked any volcanic tuff. Subsequent plasters were observed to consist of various particle sizes, predominantly in subangular shapes, a high proportion of calcareous material, and usually volcanic tuff.

A finish layer was evident on the surface of an interior floor plaster (#38). Similiar to plasters following in the sequence, this surface layer may have been burnished as it was

smooth and compacted, and contained fine-sized particles. All finish layers exhibit a dark brown color and a relative thickness of approximately 0.1 mm. Overall, there are less than ten floors from Divisions 5-2 (#38, 28, 40, 63, 70, 72, 28021) revealing finish laters. Their remaining intact is most likely a reflection of the length of their exposure.

Division 4: Samples shared a relatively smooth texture and compact plaster matrix in common. One plaster (#35) displayed a hetereogeneous texture containing calcite-based particles whose interfaces with the matrix were less distinct than those exhibited in earlier samples, suggesting it was more tightly bound within the matrix. The varying colors and shapes of the aggregates from each sample appear to be obtained from different sources. One plaster (#58) was unique by its sole inclusion of translucent particles.

Division 2: Samples, like their predecessors, exhibited both homogeneous and chaotic textures without a marked structural or compositional evolution over time. This was evidenced by the variable compaction of the matrices, and the types, shapes and sizes of the siliceous aggregates contained therein. Calcareous particles were found in much greater proportion than their siliceous counterparts. Two acid-digested plasters lacked siliceous aggregates, despite their appearance in one sample (#40) viewed in cross section. Surprisingly, an earthen plaster (#67) appeared in the early part of Divsion 2 (or late Divsion 3) which may infer it is earlier than its ascribed date.

The aggregates found within the floor plasters generally consisted of a combination of quartz sand and green volcanic tuff particles of various sizes, albeit with some anomalies. Two samples from Chachalaca contained atypical aggregate types, such as a fine-sized, gray-colored sand (#54), or the exclusive presence of red volcanic tuff (#64). A floor plaster from Rosalila (#26773-2) was composed almost entirely of green volcanic tuff aggregates, (with the exception of a few red aggregates visible in cross section.) Small pieces of shell were found in two plasters (#63 and #27306) which were likely included as an aggregate. Despite the inconsistency of the samples from Division 2, a

reduction in the amount of carbon and possibly a less chaotic matrix was apparent, particularly in the Rosalila samples. This feature, albeit inconclusive based on the small sample size, demonstrated the achievement of a purer lime-based product, suggesting increased attention or expertise involved in the manufacture of plaster.

Cross Section Examination

Features	Division 6		Division 5																		
	37	101	36	83	84	95	96	97	98	99	82	107	105	27	26	38	81	80	88	89	90
Texture: Homog.	✓		✓		✓		✓	✓			✓		✓		✓	✓					✓
Heterog.		✓		✓		✓			✓	✓		✓		✓			✓	✓	✓	✓	
Calc. Aggs.	✓	✓		✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Finish Layer																✓					
Roundness Round		✓		✓		✓	✓	✓							✓	✓					
Subround	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓
Angular							✓												✓		
Subang.	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Carbon		✓		✓	✓	✓		✓	✓	✓			✓				✓	✓			
Iron Stains			✓		✓																
Cracks	✓														✓						
Voids					✓						✓							✓			

Cross Section Examination

Features	Division 4				Division 2														
	28	34	35	58	67	40	53	54	64	63	62	61	60	59	65	70	71	72	77
Texture: Homog.		✓		✓		✓			✓	✓				✓	✓			✓	✓
Heterog.	✓		✓		✓		✓	✓			✓	✓	✓			✓	✓		
Calc. Aggs.	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓	✓	✓	✓	
Finish Layer	✓					✓				✓			✓			✓		✓	
Roundness Round	✓		✓					✓	✓	✓						✓	✓	✓	
Subround	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓	✓	✓
Angular							✓								✓				
Subang.	✓	✓	✓	✓	✓		✓								✓		✓	✓	✓
Carbon					✓	✓						✓							
Iron Stains											✓		✓						✓
Cracks	✓						✓											✓	
Voids	✓					✓											✓	✓	

Cross Section Examination

Features	Division 2: Rosalila												
	28020	28021	27306	26733 -1	26733 -2	27304	26677	26724	26719	25150	26701	26725	28024
Texture: Homog.	✓	✓										✓	✓
Heterog.			✓	✓	✓	✓	✓	✓	✓	✓	✓		
Calc. Aggs	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Finish Layer		✓								✓			
Roundness Round	✓							✓				✓	✓
Subround	✓	✓	✓		✓	✓			✓	✓			
Angular													
Subang.	✓		✓	✓		✓		✓	✓	✓	✓		✓
Carbon		✓											
Iron Stains								✓					
Cracks													
Voids									✓				

CROSS SECTION EXAMINATION	SAMPLE: 26

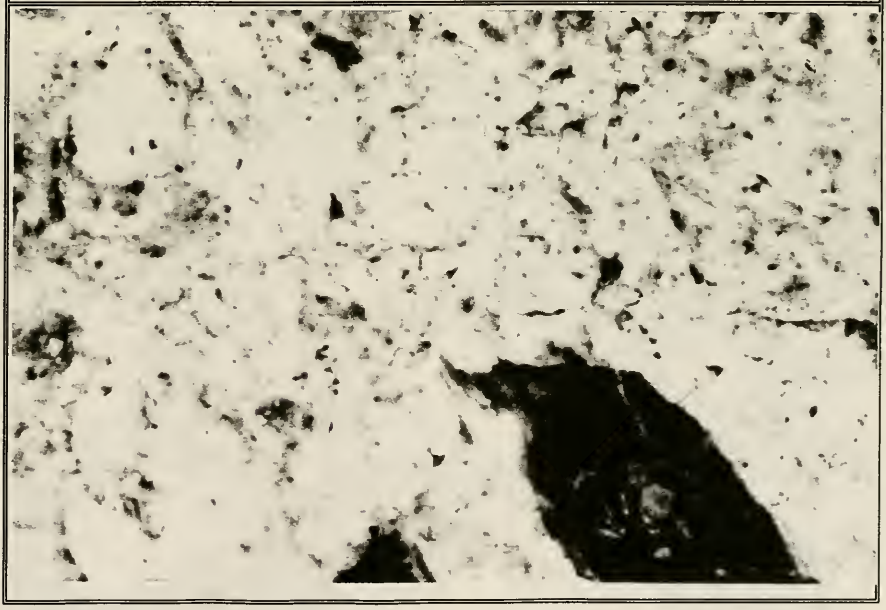
Floor Name: Bernal

Sample Location: Structure 26, South of Tartan.

Division: 5, MAS 9	**Date:** A.D. 440 - 450	**Magnification:** 6.25x

General Description:

Sample consists of a homogenous cream-colored plaster matrix. Some distinct calcite based minerals of subrounded and subangular shapes are distinguishable from the matrix. Poorly sorted particles of fine sizes are distributed throughout. Two-coarse-sized, dark brown, subangular aggregates are present, ranging between 0.2 – 0.5 mm, displaying green, brown, and translucent minerals within their matrices. Slight cracking occurs around the coarse-sized aggregate. No distinct layers are visible.



CROSS SECTION EXAMINATION	SAMPLE: 27

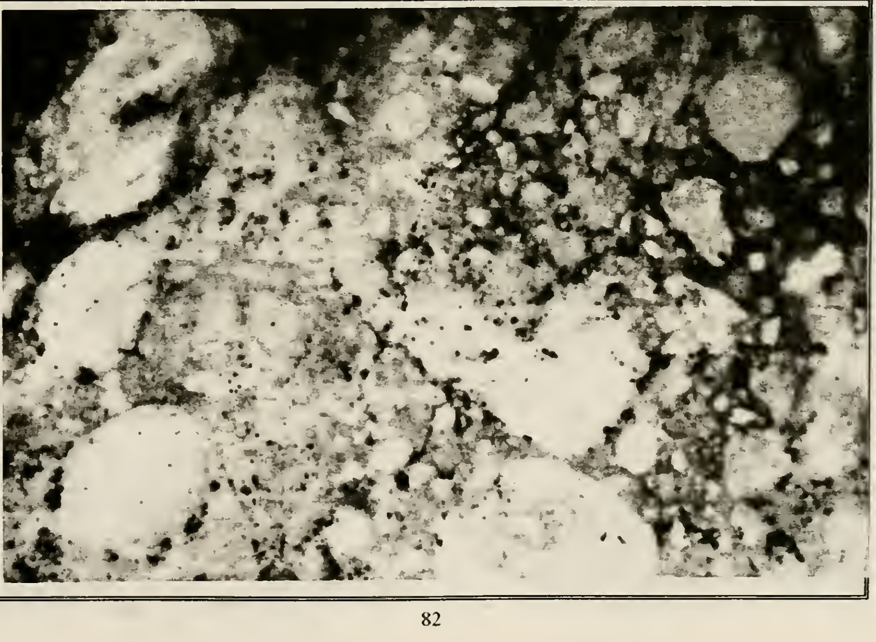
Floor Name: Mot Mot

Sample Location: Northeast Court Group, north of Tartan.

Division: 5, MAS 7	**Date:** A.D. 460 - 470	**Magnification:** 5x

General Description:

Sample consists of a heterogeneous tan-colored matrix. White and cream colored aggregates, ranging from fine to coarse sizes up to 0.2 mm are distributed throughout. They are poorly sorted and of rounded and subrounded shapes. The types of calcite-based constituents are difficult to discern due to their varying colors and textures. Several fine black particles, likely representing carbon are contained within the matrix and the calcite-based particles. A few fine-sized rust colored particles are visible. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 28

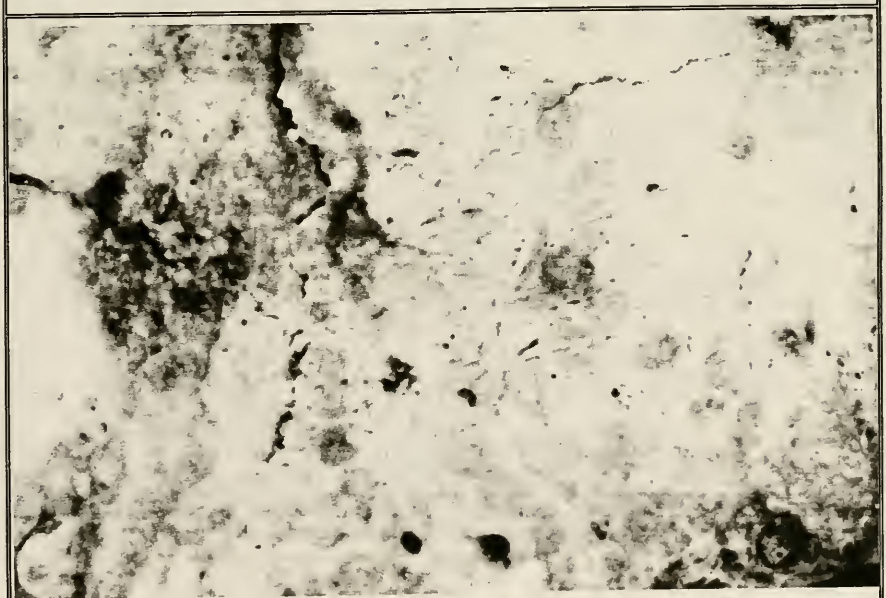
Floor Name: Division 4 Court 4C Floor (Sharer)

Sample Location: Northeast Court Group, south of Heron.

Division: 4	**Date:** A.D. 480 - 520	**Magnification:** 5x

General Description:

Sample consists of a tan and ivory-colored homogeneous plaster matrix comprising an agglomeration of spherical, calcite-based particles with indistinct boundaries. The medium size spherical particles vary in color (white, tan, ivory, and gray.) There are a few brown and rust colored particles, ranging in size from fine to medium, of subangular and subangular shapes. Large cracks penetrate one end of the sample and smaller ones occur at the opposite end. Small voids are scattered throughout, possibly occupied once by fine-sized aggregates. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 34

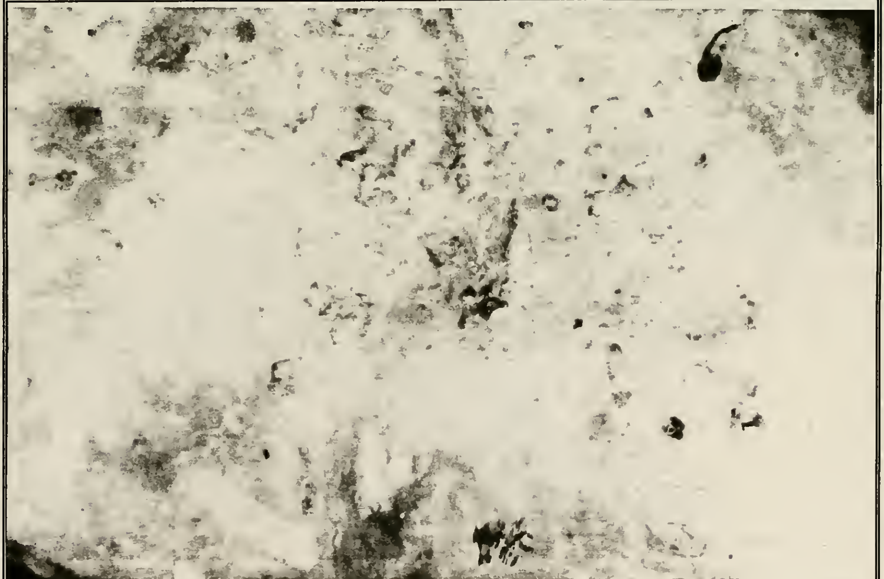
Floor Name: Gordon Floor

Sample Location: Northeast Court Group, north of Toucan.

Division: 4	Date: A.D. 480 - 520	Magnification: 7.5x

General Description:

Sample consists of a compact, homogeneous, cream and yellow-colored plaster matrix. It is fairly uniform in texture, except for a few spherical and oblong-shaped voids, measuring approximately 0.2 mm which appear to have been occupied by aggregate particles and/or air bubbles. A few calcite-based constituents and fine rust particles are present, although the latter are barely visible within the matrix. No distinct layers are discernible.



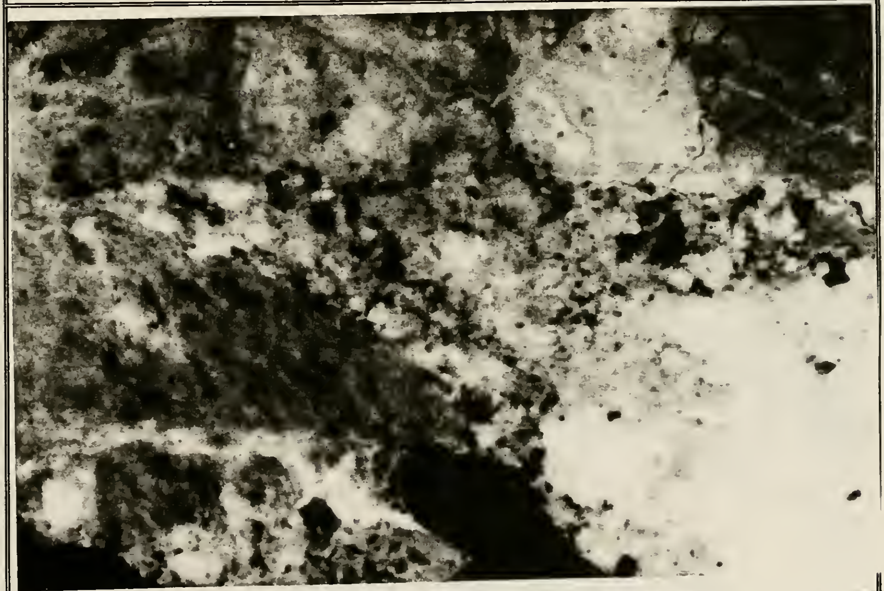
CROSS SECTION EXAMINATION	SAMPLE: 35

Floor Name: Toucan Interior

Sample Location: Northeast Court Group, inside north central doorway.

Division: 4	**Date:** A.D. 480 - 520	**Magnification:** 7.5x

General Description:
Sample consists of a compact, heterogeneous and tan-colored matrix. Poorly sorted aggregates of various colors (green, red, gray, brown, and white) of round, subround, and subangular shapes, ranging approximately from 0.5 – 1 mm are difficult to distinguish from the matrix. Calcite-based constituents are visible, ranging from fine sizes to larger regions. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 36

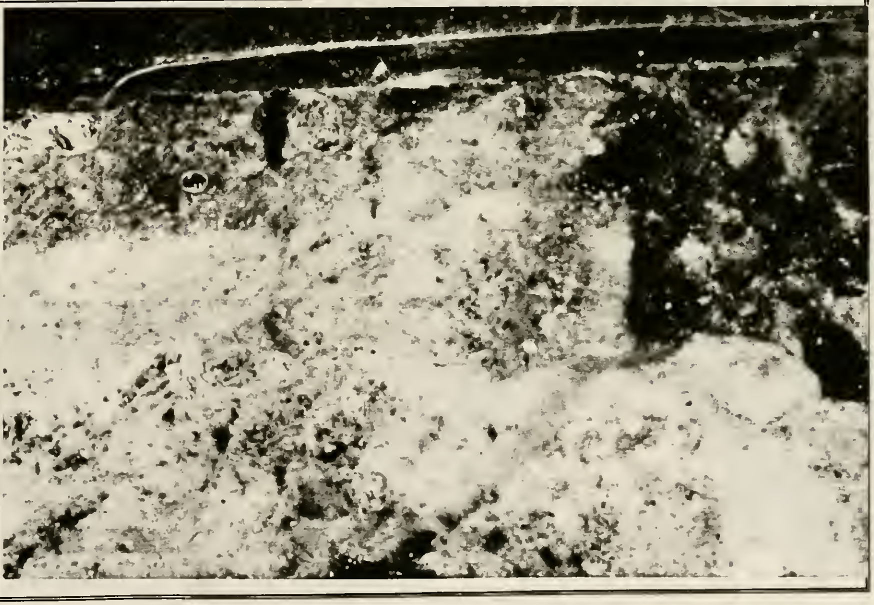
Floor Name: Papo

Sample Location: Northeast Court Group, below Loro.

Division: 5, MAS 11	**Date:** A.D. 420 – 430	**Magnification:** 7.5x

General Description:

Sample consists of a coarse-sized aggregate coated with a thin layer of plaster. The particle is bright yellow with a red mineral inclusion located on one end, and several fine-sized tranlucent minerals scattered throughout. The thin plaster layer coating the particle is a homogeneous, reddish-brown colored matrix with very fine particles. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 37

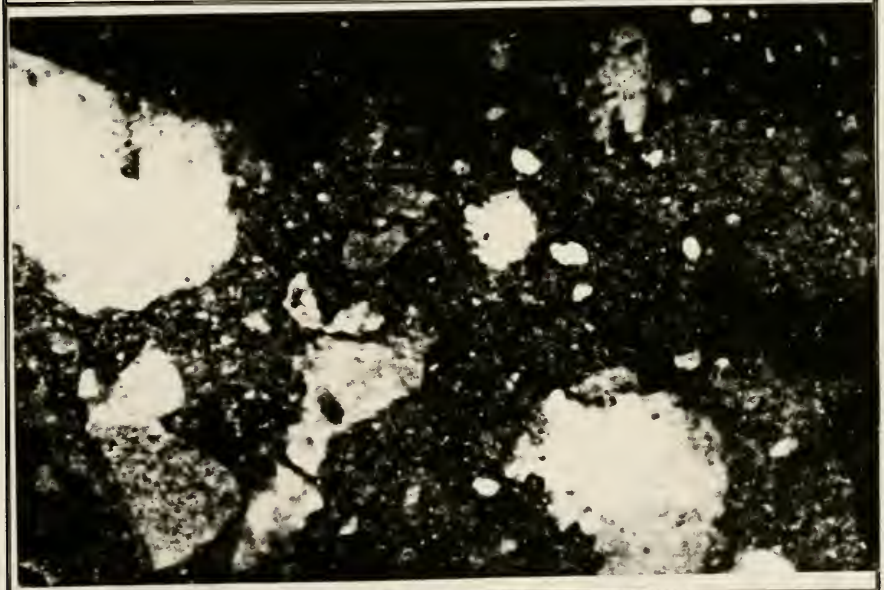
Floor Name: Chinchilla

Sample Location: Northeast Court Group, below Loro.

Division: 6	**Date:** A.D. 250 - 420	**Magnification:** 5x

General Description:

Sample consists of an earthen plaster. Poorly sorted aggregates, consisting of lime-based particles, volcanic tuff and sand which varies in color (brown and red) ranging from fine to medium sizes, between 0.1 – 0.7 mm. The majority of particles exhibit subrounded and subangular shapes, with some irregular surfaces. Cracking occurs in the middle of the sample. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 38

Floor Name: Loro

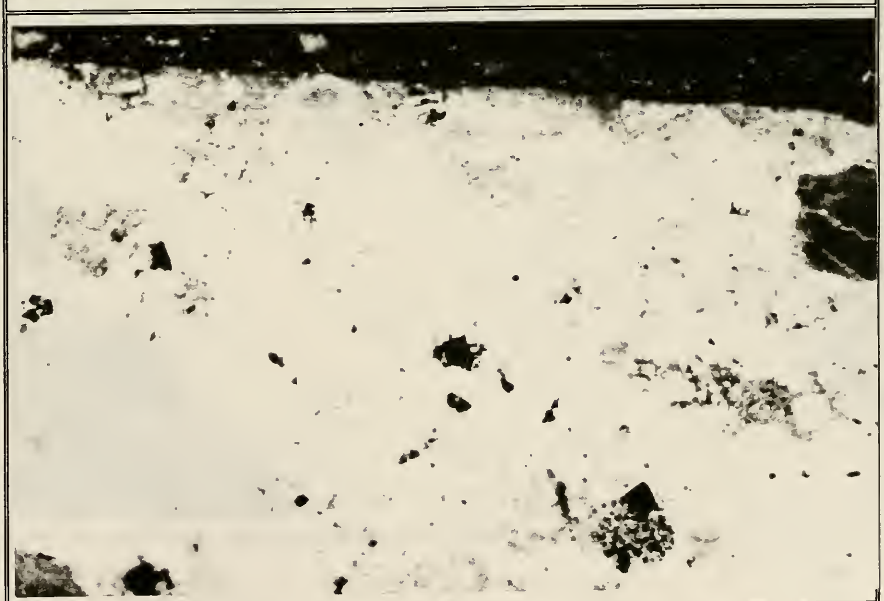
Sample Location: Northeast Court Group, 2 meters within south central door.

Division: 4	Date: A.D. 480 - 520	Magnification: 5x

General Description:

Sample consists of a heterogeneous cream-colored plaster matrix including an agglomeration of subrounded particles. Subangular and subrounded aggregates of various colors (green, rust, gray, and brown) ranging from fine to coarse sizes, up to 0.3 mm are distributed throughout. Medium to coarse-sized calcite based particles of spherical and oblong shapes are visible.

The finish layer, measuring 0.1 mm, appears very dense and consists of fine particle inclusions. The brown matrix contains various colored aggregates (green, brown, and gray). A vertical crack penetrates the finish layer.



CROSS SECTION EXAMINATION	SAMPLE: 40

Floor Name: Ganso Interior

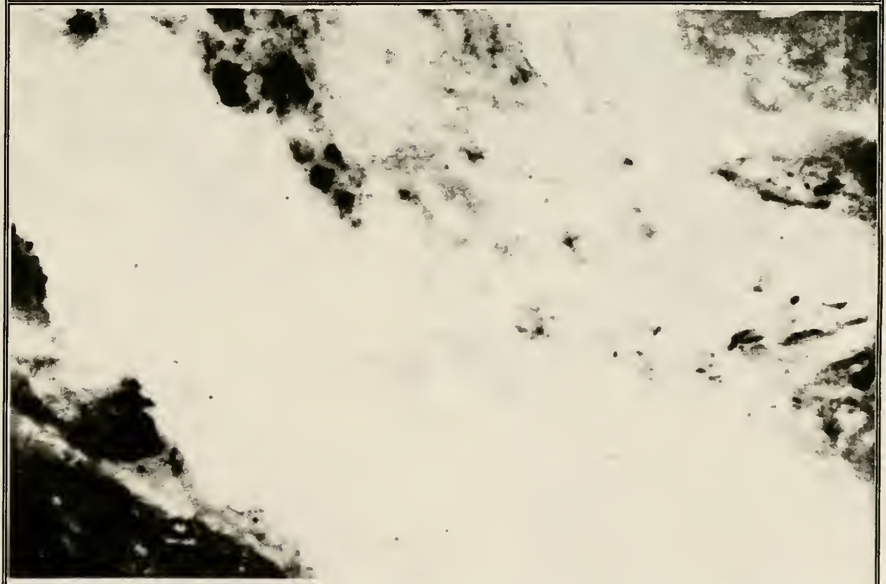
Sample Location: Northeast Court Group, north room.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

General Description:

Sample consists of a homogeneous plaster matrix of varying shades of white and cream. Spherically-shaped voids are present within the matrix where particles may have once occupied. A few dark gray and brown particles of fine to medium sizes and subangular shapes are visible. Trace amounts of black-colored particles are present, most likely indicating carbon from burnt fuel.

The dense finish layer is rust colored, likely from iron oxides, and contains a greater proportion of fine sized particles, measuring approximately 0.15 mm.



CROSS SECTION EXAMINATION	SAMPLE: 53

Floor Name: Division 2 Court

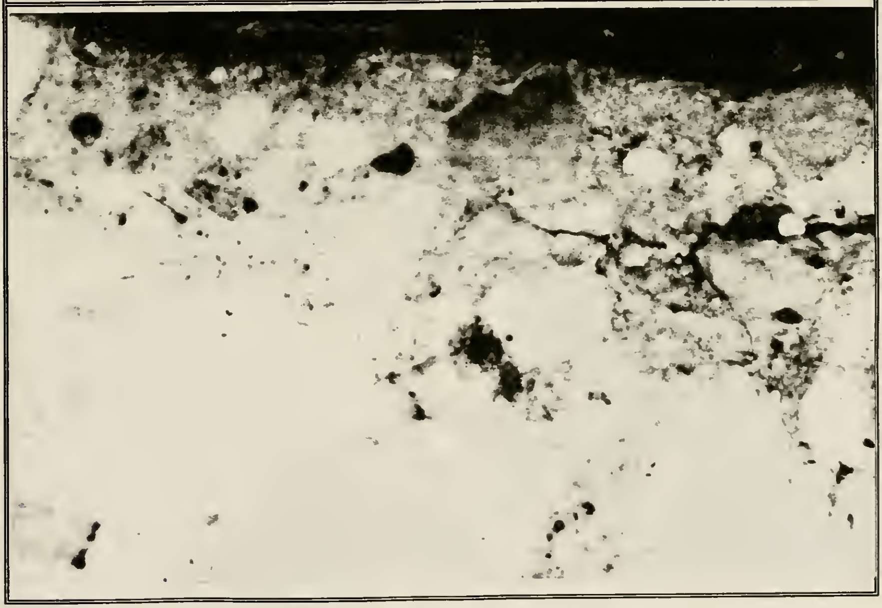
Sample Location: Northeast Court Group, south of Chachalaca.

Division: 2	Date: A.D. 540 - 650	Magnification: 5x

General Description:

Sample consists of a cream colored plaster matrix with a chaotic texture. Fine to coarse-sized particles, ranging from 0.1 to 0.15 mm, which vary in color from white to cream and appear to be much denser than the surrounding matrix, possibly indicating limestone aggregates. A partial crack runs parallel to the finish layer. Poorly sorted aggregates ov various colors (orange, brown, pink, green, gray, and red), some semi-translucent, of angular, subangular and subrounded shapes.

A rust-colored finish layer, measuring approximately 0.05 mm, is denser and contains well sorted fine-sized particles.



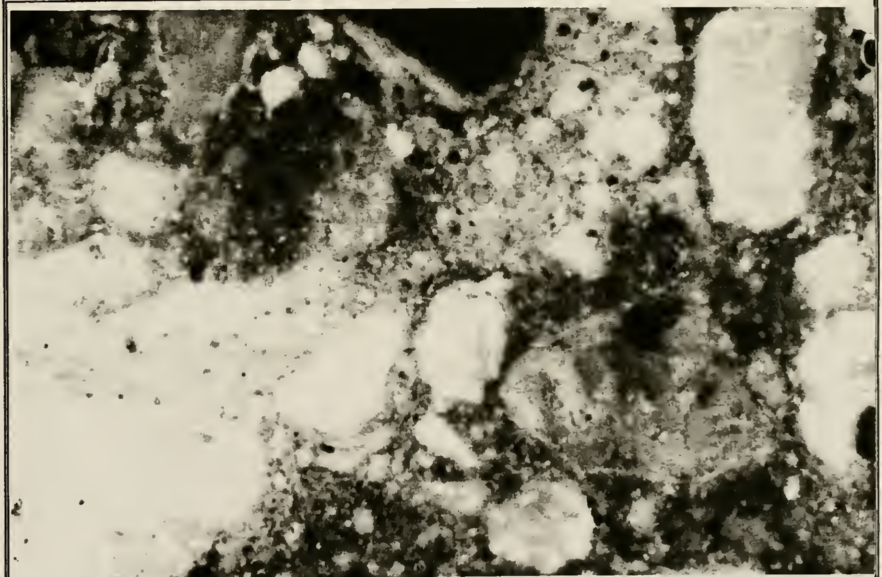
CROSS SECTION EXAMINATION	SAMPLE: 54

Floor Name: Chachalaca Interior

Sample Location: South side, side of ripped out bench.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 6.25x

General Description:
Sample consists of a heterogeneous and compact tan-colored plaster matrix. (The variation in color is due to the resin penetrating the matrix.) Poorly sorted aggregates of various sizes and colors (brown, yellow, white, green, red) are present and subrounded, subangular, and angular shapes are present. Calcite-based particles in varying shades of white to cream indicate limestone fragments. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 59

Floor Name: Chachalaca, Floor #1

Sample Location: Northeast Court Group, abuts east side. Last plaza surface.

Division: 2	**Date:** A.D. 540 - 650.	**Magnification:** 5x

General Description:
Sample consists of a compact homogeneous red-colored matrix, possibly indicating volcanic tuff. A few fine-sized aggregates of subangular shapes are visible, particularly within the fine crack which occurs in the center of the sample. No layers are discernible.

CROSS SECTION EXAMINATION	SAMPLE: 60

Floor Name: Chachalaca, Floor #2

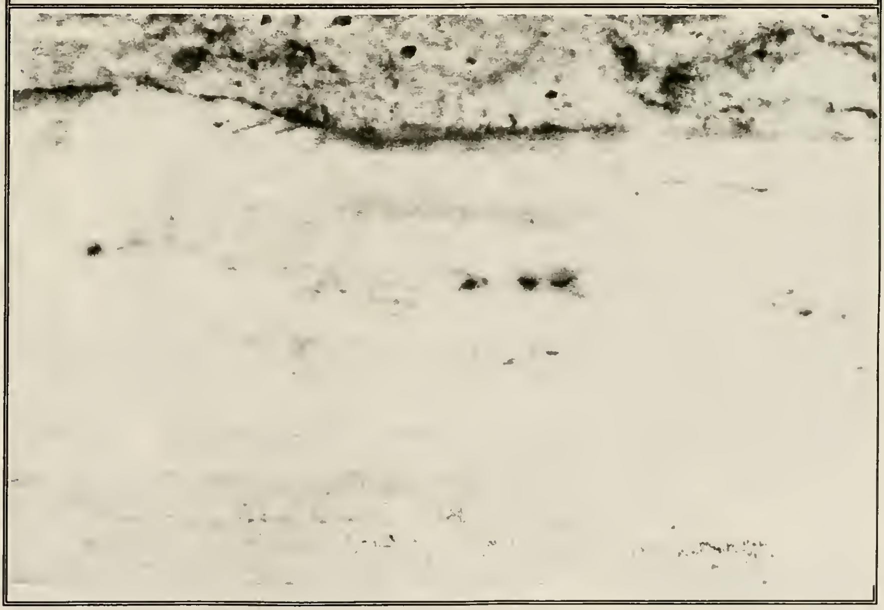
Sample Location: Northeast Court Group, penultimate plaza floor on east side.

Division: 2	**Date:** A.D. 540 – 650	**Magnification:** 5x

General Description:

Sample consists of a compact, homogeneous matrix with varying shades of cream and white. Within the ground layer, there are striations, but no distinct layers or aggregates. Rust stains are present throughout the matrix.

The finish layer, measuring approximately 0.2 mm, is cream-colored with some fine particles visible. It is difficult to discern shapes and sorting since their edges are not distinguishable.



CROSS SECTION EXAMINATION	SAMPLE: 61

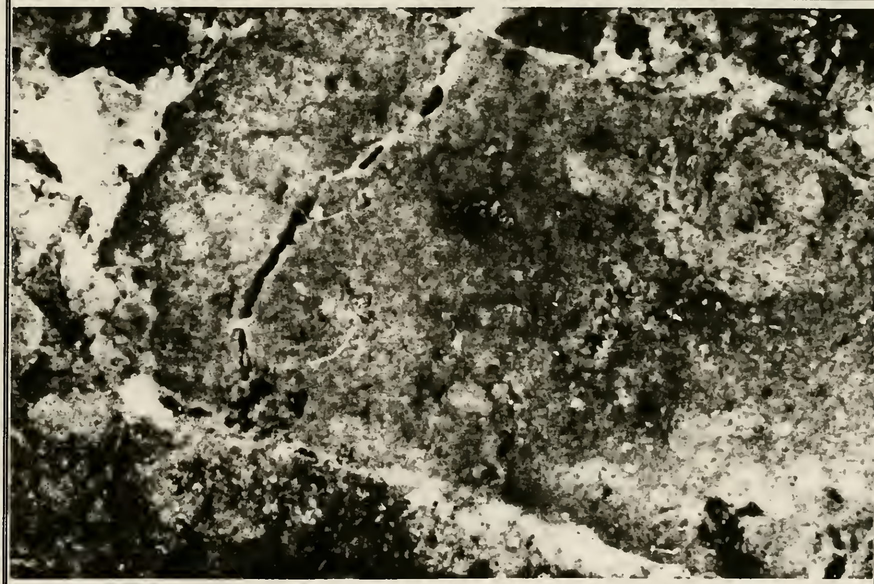
Floor Name: Chachalaca, Floor #3

Sample Location: Northeast Court Group, 3rd Plaza surface above top of Indigo.

Division: 2	Date: A.D. 540 – 650	Magnification: 5x

General Description:

Sample consists of a heterogeneous plaster matrix which is relatively compact, containing particles of a white and cream colors in various sizes. The sample is dominated by a large green tuff aggregate, measuring approximately 0.8 mm, surrounded by smaller tuff particles and various colored aggregates (brown and rust) of subangular and subrounded shapes. A crack runs the width of the coarse aggregate which appears to be partially filled in with calcareous material. There are some black regions, possibly indicating carbon. No layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 62

Floor Name: Chachalaca, Floor #4		
Sample Location: Northeast Court Group, 2nd Plaza Surface above top of Indigo.		
Division: 2	**Date:** A.D. 540 – 650	**Magnification:** 7.5x

General Description:

Sample is dominated by a gray coarse-sized aggregate, measuring 1.3 mm, and containing white veins throughout. The surrounding chaotic plaster matrix is compact and has an orange cast, most likely the result of iron staining. Within the matrix, fine aggregate particles varying in color (orange, brown, and red) and of subangular shapes are present. No layers are discernible.

CROSS SECTION EXAMINATION	**SAMPLE:** 63

Floor Name: Chachalaca, Floor #5.

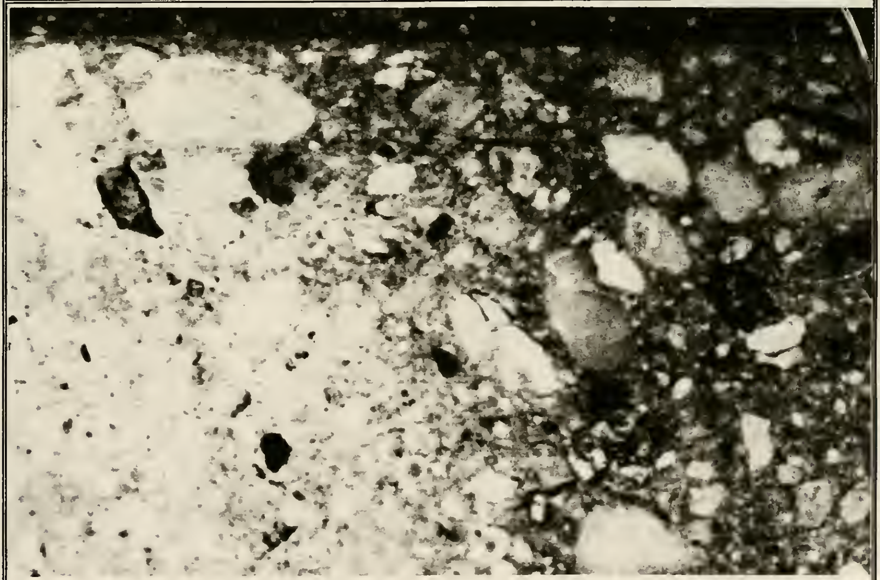
Sample Location: Northeast Court Group, 1st Plaza surface above top of Indigo.

Division: 2	**Date:** A.D. 540 – 650..	**Magnification:** 5x

General Description:

Sample consists of a chaotic and compact plaster matrix. Within the tan-colored matrix are poorly sorted aggregates of various colors (gray, tan, orange, yellow, green, rust, pink, cream, and white) and are subangular, rounded and subrounded shapes. A shell fragment is visible on the surface. The white and tan particles, possibly indicating limestone aggregates, measuring approximately 0.1 mm, are both opaque and translucent.

The finish layer, measuring approximately 0.1 mm, is a dark brown and denser than the ground layer. The fine particles are well sorted and subangular and subrounded in shape.



CROSS SECTION EXAMINATION	SAMPLE: 65

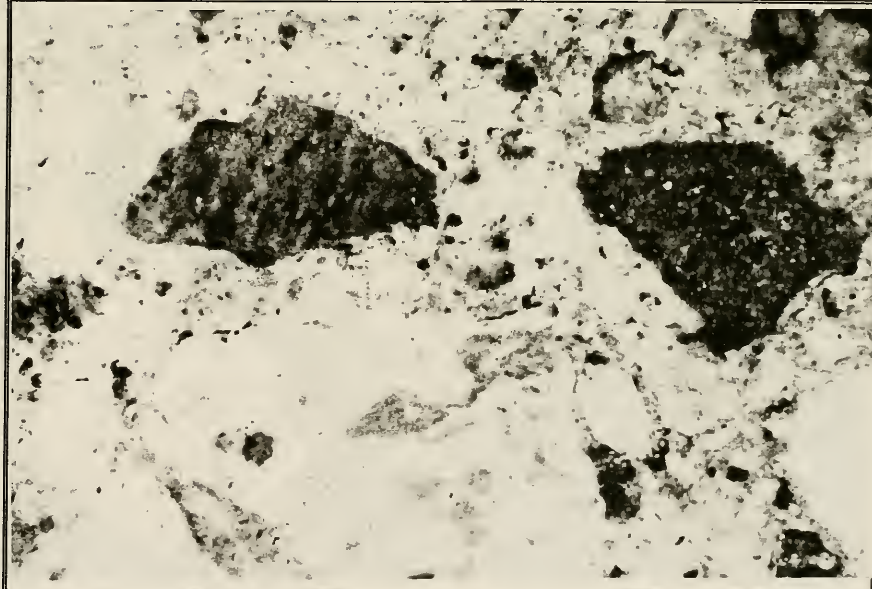
Floor Name: Chachalaca, Floor #7

Sample Location: Northeast Court Group, 169-172 sm above last Div. 2 plaza surface.

Division: 2	Date: A.D. 540 – 650	Magnification: 5x

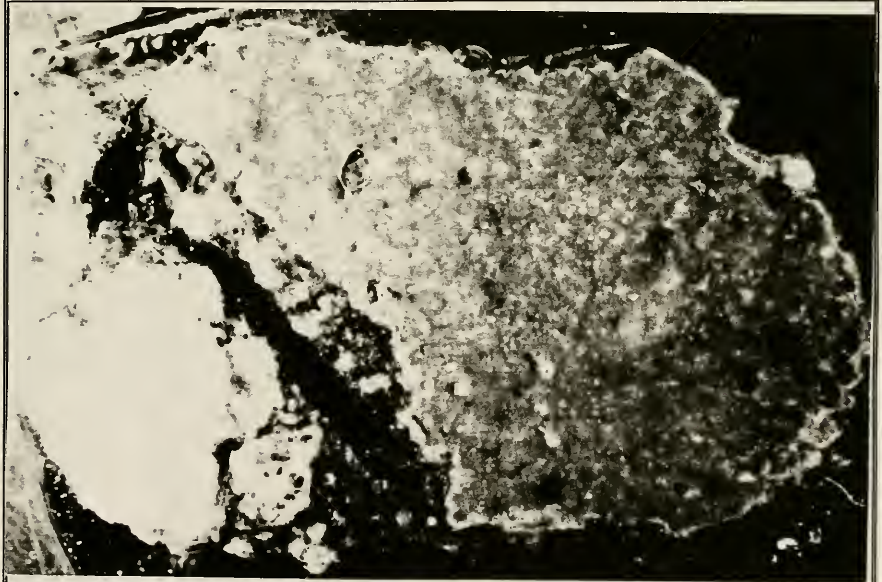
General Description:

Sample consists of a chaotic tan-colored matrix. Poorly sorted aggregates of various colors (rust and gray, green, yellow, pink and white), ranging from 0.2 – 0.4 mm, are evenly distributed throughout the matrix. Several white and cream colored aggregates, ranging from 0.1 – 0.5 mm, which vary in density and shape are present, most likely representing limestone fragments. The aggregate particles are rounded, subangular, and subrounded in shape and vary in size from fine to coarse. No distinct layers are discernible.



CROSS SECTION EXAMINATION		SAMPLE: 67
Floor Name: Indigo		
Sample Location: Northeast Court Group, floor upon which Indigo rests.		
Division: 2	**Date:** A.D. 540 – 650	**Magnification:** 7.5x

General Description:
Sample consists of a porous brown-colored chaotic matrix containing poorly sorted aggregates of various colors (green, brown, rust, yellow, pink, and white) of subrounded and subangular shapes. The matrix is dominated by a coarse-sized green tuff aggregate, measuring 1.2 mm, containing various colored minerals. The next largest aggregate is a white medium-sized aggregate, measuring 0.4 mm, and most likely a limestone fragement. A large strip of black, 0.6 mm in length, most likely representing carbon, separates the two aggregates within the matrix. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 70

Floor Name: 22 Chiquito

Sample Location: Northeast Court Group, atop highest terrace, north side.

Division: 2	Date: A.D. 540 – 650	Magnification: 7.5x

General Description:
Sample consists of a chaotic tan-colored plaster matrix. Varying shades of white and cream colored particles in fine to coarse sizes are present, likely indicating limestone aggregates. The colored aggregates (brown, rust, pink, yellow, gray and green) vary in size from fine to coarse and are of subangular and subrounded shapes. Fine-sized black particles are visible, likely indicating carbon. No layers are discernible.

CROSS SECTION EXAMINATION	SAMPLE: 71

Floor Name: 22 Chiquito

Sample Location: Northeast Court Group. 1st Floor burying top of Chiquito.

Division: 2	**Date:** A.D. 540 – 650	**Magnification:** 5x

General Description:

Sample consists of a tannish-pink colored plaster matrix with a chaotic texture of calcite-based constituents, such as limestone aggregates in various sizes distinguishable from the surrounding matrix. Varying shades of white and cream are exhibited in the particles and matrix. Rust and orange-colored particles in fine to coarse sizes are also present. The particle shapes are subangular and subrounded. It is moderately compact with voids where particles may have occupied. There are no discernible layers.

CROSS SECTION EXAMINATION	SAMPLE: 72

Floor Name: 22 Chiquito

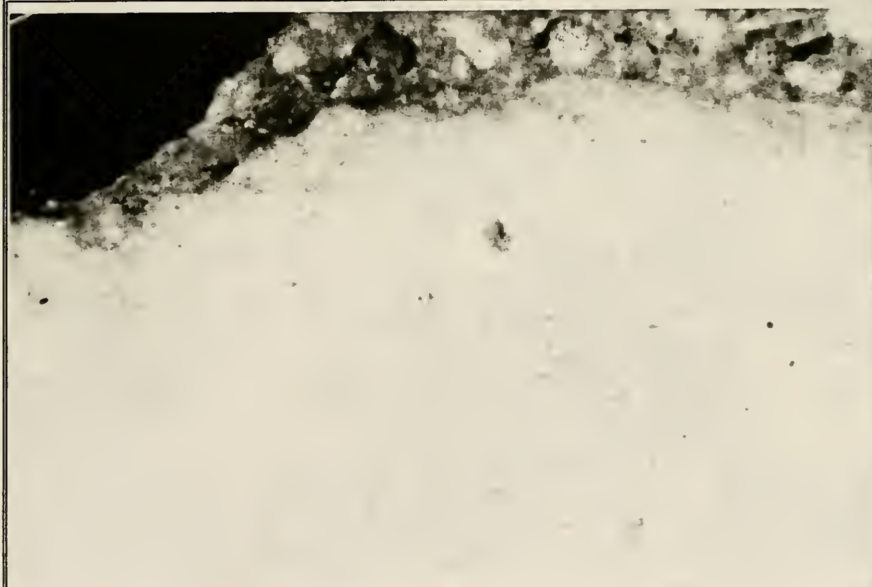
Sample Location: Northeast Court Group, 2nd Floor burying Chiquito, north side.

Division: 2	**Date:** A.D. 540 – 650	**Magnification:** 5x

General Description:

Sample consists of a preparatory plaster layer and a finish layer. The ground layer is a cream-colored homogeneous matrix with few visible aggreates. The subrounded and subangular shaped particles are light brown and translucent, and fine to coarse sized. Voids in the plaster may have been occupied by fine particles. Several small cracks are visible. The darker shade below the finish layer is from the resin which has penetrated the matrix.

The finish layer, 0.1 mm thick, is denser and darker than the substrate. Moderately sorted particles of various color (brown, rust, pink white and yellow) of subrounded and subangular shapes are visible within the layer.



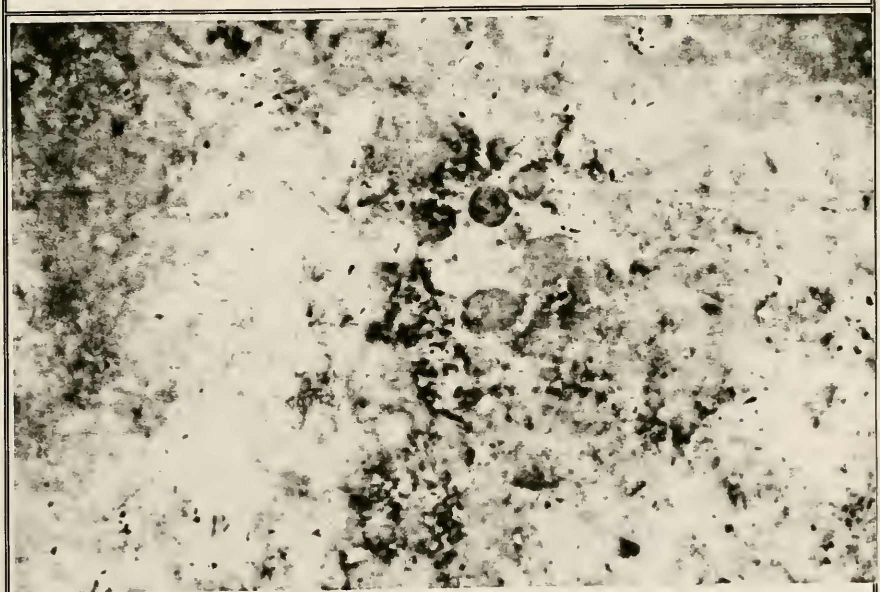
CROSS SECTION EXAMINATION	SAMPLE: 80

Floor Name: Division 5 Bernal

Sample Location: MAS, at juncture with Chaj.

Division: 5, MAS 7	**Date:** A.D. 460 470	**Magnification:** 5x

General Description:
Sample consists of a compact tan-colored homogeneous plaster matrix. Indistinct areas of varying shades of white and tan, indicating various calcite-based constituents. Voids are visible, measuring 0.05 mm, presumably occupied once by fine-sized particles. Moderately sorted aggregates of various colors (tan, brown, rust and gray), of subangular and rounded shapes are present. Fine black-colored particles may indicate the presence of carbon. No distinct layers are discernible.



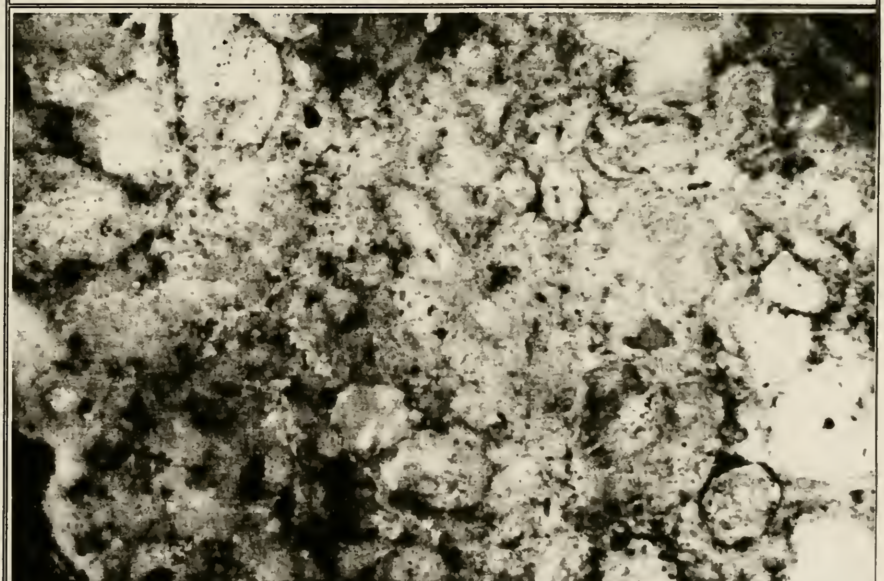
CROSS SECTION EXAMINATION	SAMPLE: 81

Floor Name: Chaj

Sample Location: MAS, under Acatan, abuts Ceiba, north side.

Division: 5, MAS 7	**Date:** A.D. 460 470	**Magnification:** 5x

General Description:
Sample consists of a chaotic, compact, ivory and gray-colored plaster matrix. Aggregates and regions which vary in shades of white and cream and are poorly sorted dominate the matrix. There are fine-sized particles ranging in color (brown, rust, green, and yellow) which are rounded, subrounded and subangular. The black region likely indicates carbon. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 82

Floor Name: Xox

Sample Location: MAS, runs under Acatan and Ceiba, abuts north side of Cedro.

Division: 5, MAS 7	**Date:** A.D. 460 470	**Magnification:** 5x

General Description:

Sample consists of a homogeneous, compact, and cream-colored plaster matrix. It is very dense except for the areas containing voids which appear to have contained fine-sized aggregates. A few rust and brown-colored medium-sized aggregates are visible, measuring approximately 0.1 mm, which are subangular and well sorted. Fine to coarse-sized white regions of round and elongated shapes are present. No distinct layers are discernible.

CROSS SECTION EXAMINATION	SAMPLE: 83

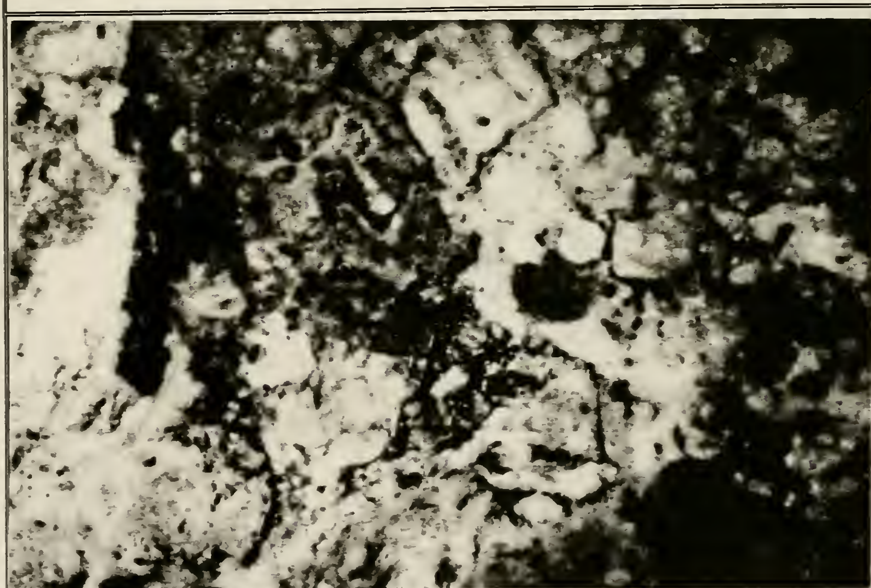
Floor Name: Pec

Sample Location: MAS, runs under Caoba.

Division: 5, MAS 11	Date: A.D. 420 - 430	Magnification: 10x

General Description:

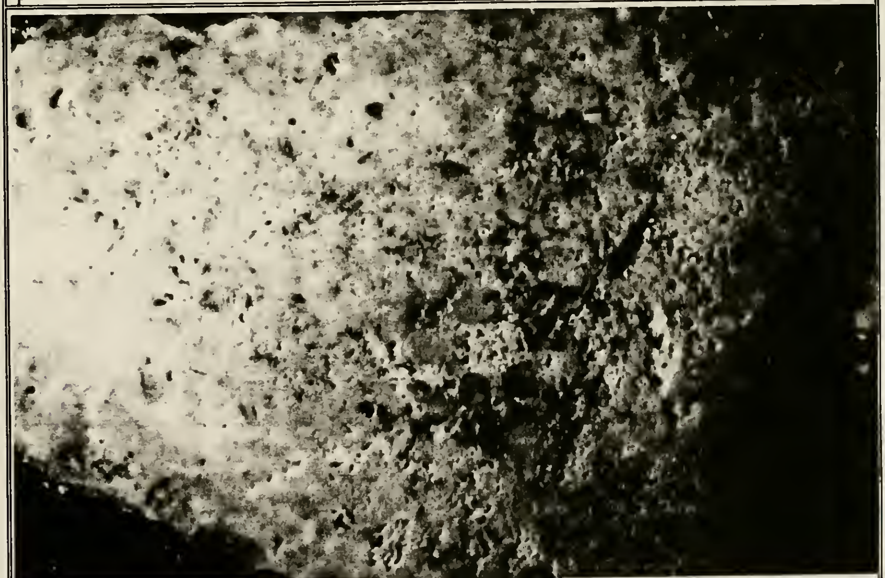
Sample consists of a chaotic, porous, and ivory-colored plaster matrix punctuated by several black areas representing carbon. The characteristics of the red-colored tuff aggregates are distinguishable since their interfaces with the plaster matrix are blurred. Aggregates and zones of white and cream colors exhibiting different calcite-based components, such as limestone fragments or recrystallized calcite are present. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 84	
Floor Name: Lu		
Sample Location: MAS, Runs under Margarita, north side.		
Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 7.5x

General Description:

Sample consists of a compact and homogeneous tan-colored plaster matrix. Several fine-sized vacuoles, measuring approximately 0.05 mm are visible throughout the matrix which appear to have resulted from air bubbles and/or particles which may have escaped. A dark shade of brown occupying the center of the sample may be carbon-based or fine-sized aggregates deeply embedded within the matrix. Traces of rust-colored iron stains are scattered throughout. No distinct layers are discernible; the darker color appearing at the edge of the sample is due to the resin penetrating the plaster.



CROSS SECTION EXAMINATION	SAMPLE: 88

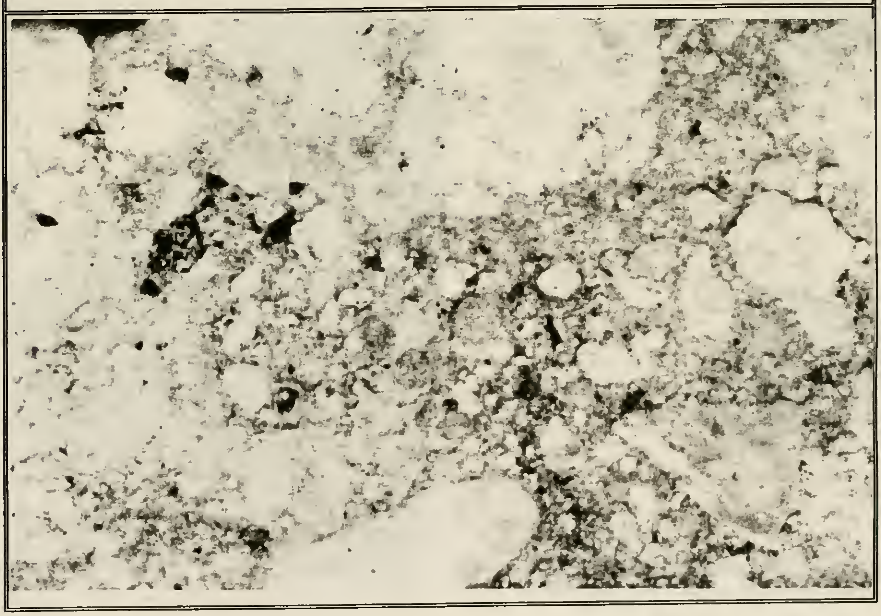
Floor Name: Bringuez

Sample Location: MAS, west of Tuna. Central area of west side.

Division: 5, MAS 7	**Date:** A.D. 460 - 470	**Magnification:** 5x

General Description:

Sample consists of a heterogeneous tan-colored plaster matrix. Fine to coarse-sized particles displaying various shades of white and cream colors are distributed throughout the matrix. They are poorly sorted and exhibit angular, subangular, rounded and subrounded shapes. Visible in a lesser proportion are well sorted, multi-colored aggregates (orange, brown, green, and gray), measuring approximately 0.1 mm, of subrounded and subangular shapes. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 89

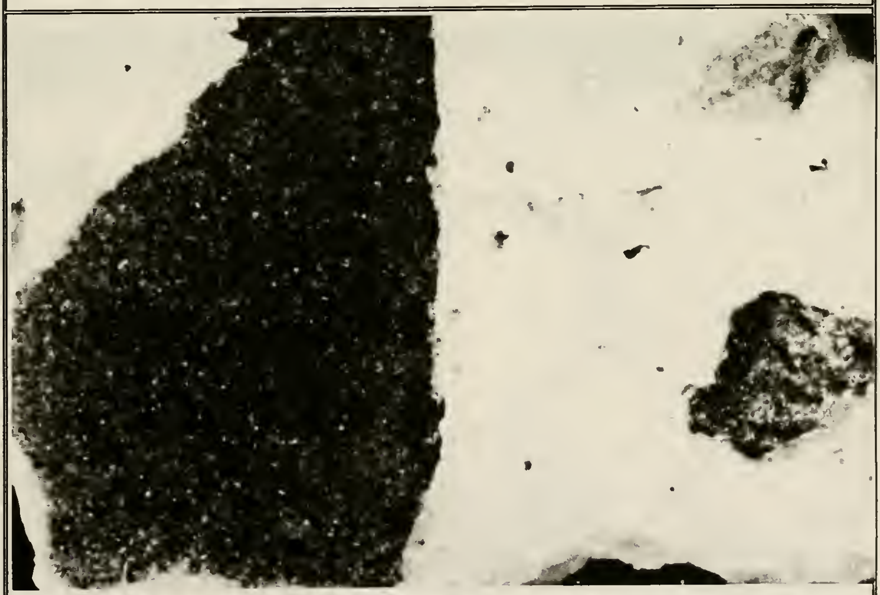
Floor Name: Reina

Sample Location: MAS, West of central area of west side of Tuna.

Division: 5, MAS 7	**Date:** A.D. 460 - 470	**Magnification:** 7.5x

General Description:

Sample consists of a homogeneous cream and white-colored, compact plaster matrix. The particles are poorly sorted and of subrounded and subangular shapes. A coarse-sized, rust colored particle, measuring 0.5 mm, containing fine gray and black grains, occupies approximately one-third of the sample. Following in size is a subrounded, gray and brown-colored aggregate, measuring 0.15 mm, with an undulating surface. The remainder of the sample is occupied by a few visible fine-sized, rust colored particles. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 90

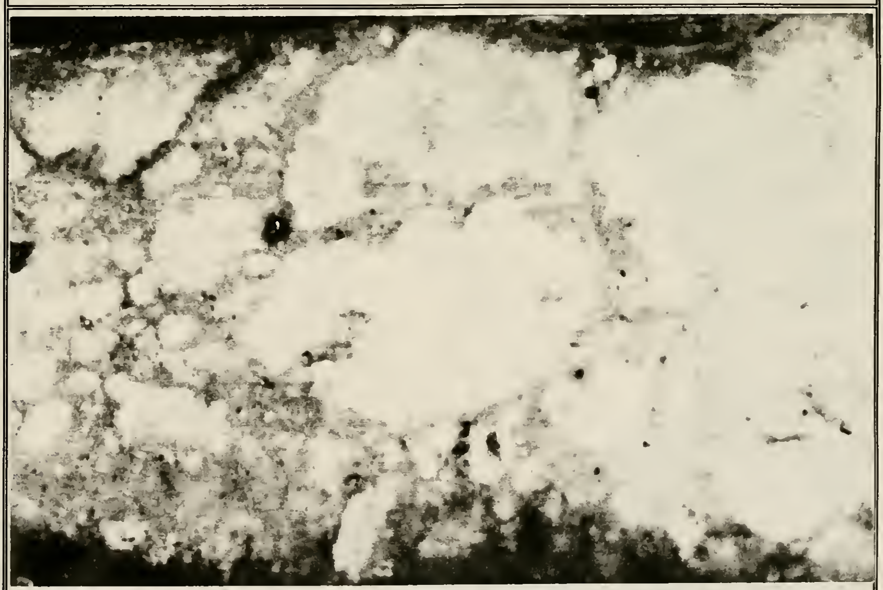
Floor Name: Banano

Sample Location: MAS, west of Tuna.

Division: 5, MAS 7	**Date:** A.D. 460 - 470.	**Magnification:** 10x

General Description:

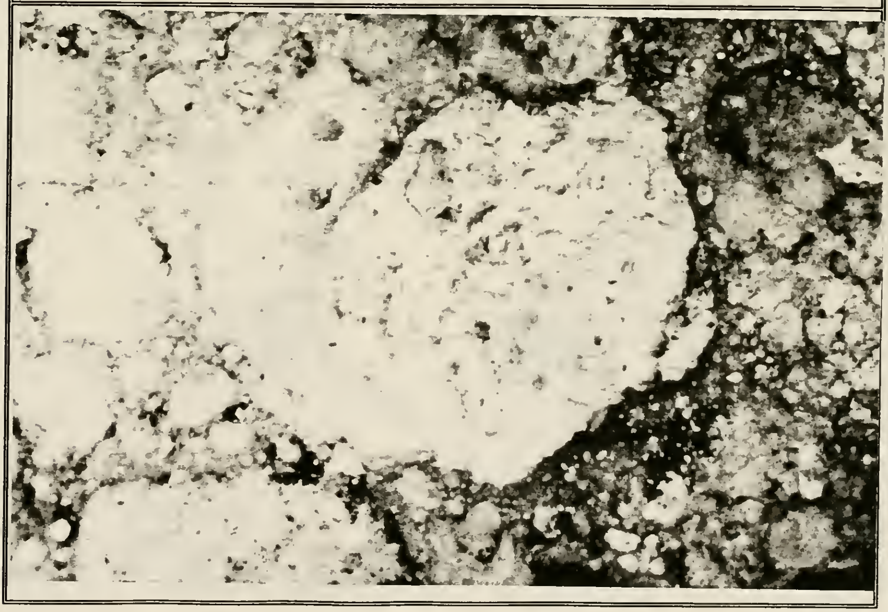
Sample consists of a heterogeneous and compact, tan-colored matrix. Poorly sorted white and cream-colored aggregates ranging from fine to coarse sizes, of subangular and subrounded shapes, are distributed throughout the matrix. Some particles exhibit a solid color, and others varying shades, possibly indicating different types of calcite-based constituents. A few fine-sized rust-colored particles are visible as well as black particles, likely representing carbon. No distinct layers are discernible.



CROSS SECTION EXAMINATION		SAMPLE: 95
Floor Name: Asmen		
Sample Location: MAS, west of Margarita, under Tuna.		
Division: 5, MAS 9	**Date:** A.D. 440 - 450	**Magnification:** 5x

General Description:

Sample consists of a heterogeneous, tan-colored plaster matrix. Poorly sorted calcite-based aggregates, indicating limestone aggregates, measuring up to 0.1 mm, of rounded and subrounded shapes dominate the matrix. A large zone in the center of the matrix consists of a calcite-based particle. The encompassing matrix is darker in concentrated regions which may represent fine-sized brown particles and/or carbon material. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 97

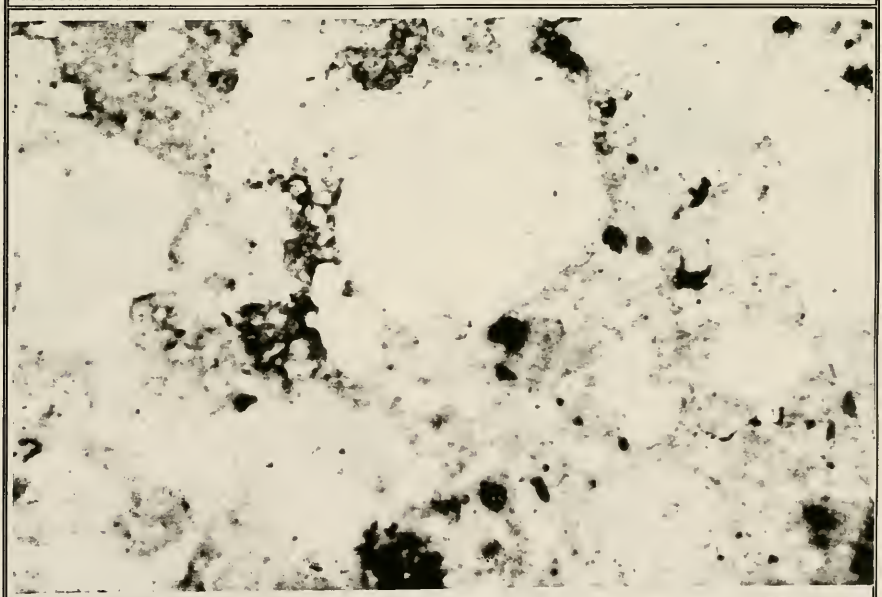
Floor Name: Flores

Sample Location: MAS, top of Margarita, west side.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 5x

General Description:

Sample consists of a compact, heterogeneous and cream-colored plaster matrix. Various shades of tan and white in round, subround and subangular shapes are clearly distinct from the matrix. Two large regions presumably indicating limestone fragments, measuring between 1 – 2 mm, contain subround and subangular shapes in their interior. Dark brown and black particles are distributed throughout the plaster, likely indicating carbon or dark-colored aggregates. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 98

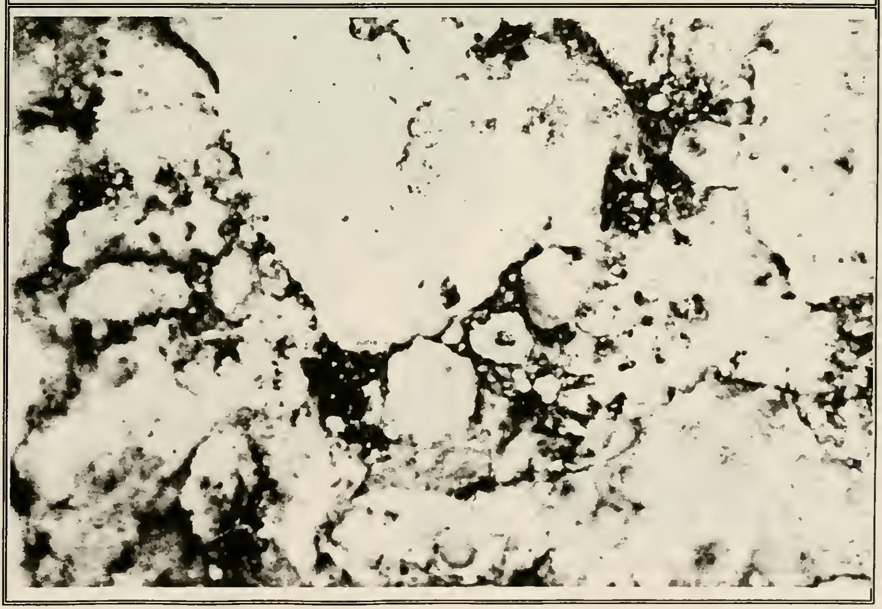
Floor Name: Cruz

Sample Location: MAS, tops step up of Margarita platform on west side.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 5x

General Description:

Sample consists of a chaotic, cream and tan-colored plaster matrix displaying an agglomeration of at least 60% calcite-based constituents of fine to coarse sizes and mostly rounded and subrounded shapes. The particles may represent limestone fragments, lime covered sand particles, or recrystallized calcite. Within the larger regions, the shades vary (white, cream, and tan). The particle edges are well defined by ferrous or carbonaceous material, or fine-sized brown aggregates. The dark material spreads throughout part of the matrix in concentrated areas. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 99

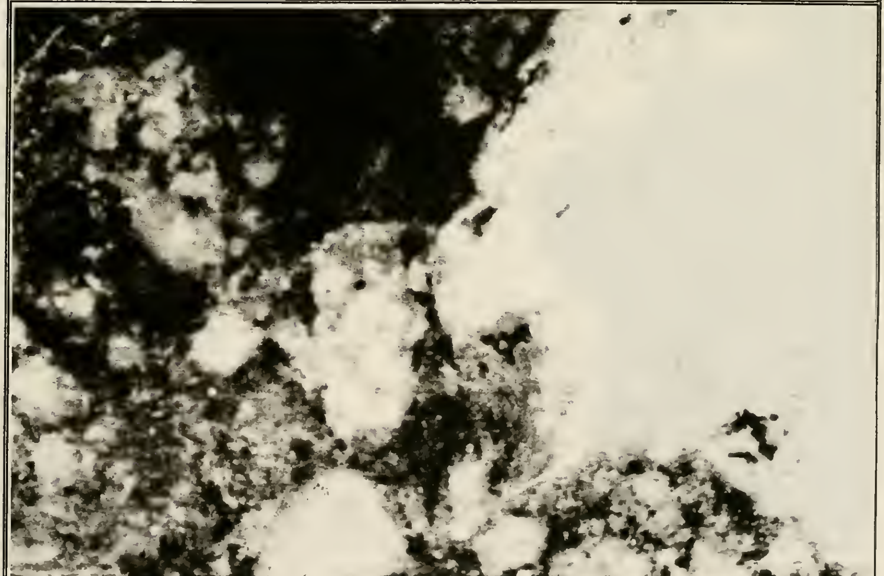
Floor Name: Burkett

Sample Location: MAS, interior floor of Margarita, Xuk Pi, west side.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 7.5x

General Description:

Sample consists of a heterogeneous plaster matrix. Poorly sorted aggregates of various colors (green, gray, brown, yellow, and rust), of rounded, subrounded and subangular shapes are located in concentrated areas. Masses of white, calcareous regions in various sizes, possibly representing limestone fragments or recrystallized calcite, are present within the matrix. Large black areas, measuring approximately 0.3 mm, likely indicate carbon. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 101

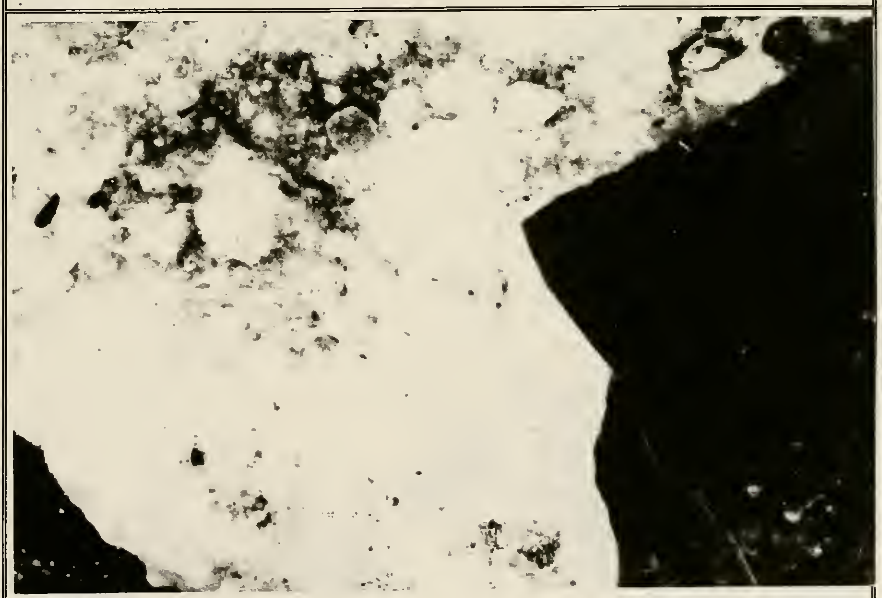
Floor Name: Hun Nal

Sample Location: MAS, first platform under Margarita.

Division: 6	Date: A.D. 250 - 420	Magnification: 10x

General Description:

Sample consists of a cream-colored heterogeneous plaster matrix. A coarse-sized subangular, brown-colored particle, measuring 0.8 mm, is located at the edge of the plaster. Brown and rust-colored fine particles, and fine to coarse-sized calcite-based particles, possibly indicating limestone fragments of rounded and subrounded shapes, are visible. The dark bown region may indicate the presence of carbon or dark fine-sized particles embedded in the matrix. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 105

Floor Name: Barientos

Sample Location: MAS, abuts west side of Papa steps.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 5x

General Description:
Sample consists of a heterogeneous ivory-colored plaster matrix. Several aggregates and zones of varying shades of white and cream colors are present, possibly representing limestone aggregates. Particles range in size from medium to coarse, up to 3mm, are primarily of subangular and subrounded shapes. Poorly sorted siliceous aggregates of various colors (green, rust, and brown) are also present. No distinct layers are discernible.

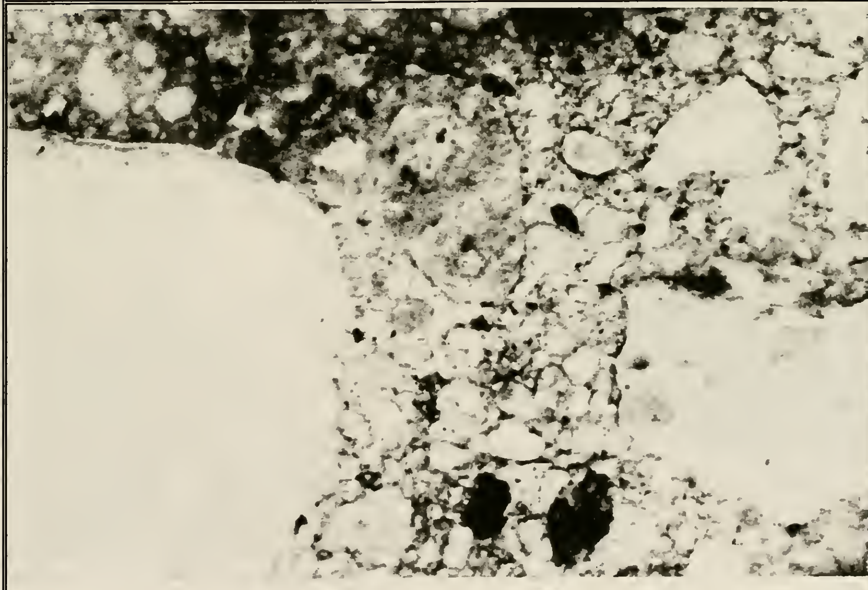
CROSS SECTION EXAMINATION	SAMPLE: 107

Floor Name: Ramirez

Sample Location: MAS, integral with base of Papa.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 7.5x

General Description:
Sample consists of a heterogeneous, porous, and tan-colored plaster matrix. Several aggregates and zones of varying shades of white and cream are present, possibly indicating limestone aggregates. The calcareous regions are distinguished by different textures and degrees of compaction. They exhibit rounded, subrounded and subangular shapes. Fine to medium-sized aggregates, up to 0.2 mm, of subrounded and subangular shapes of various colors (brown, rust, and gray) are visible. No distinct layers are discernible.



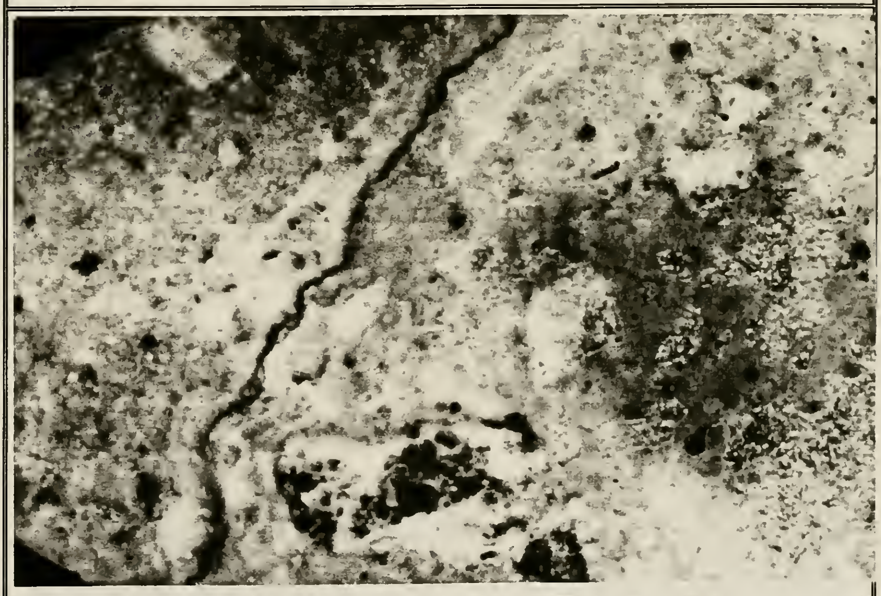
CROSS SECTION EXAMINATION	SAMPLE: 25150

Floor Name: Piso Don Jorge

Sample Location: Rosalila. cancels Azul on west side.

Division: 2	Date: A.D. 540 - 650	Magnification: 7.5x

General Description:
Sample consists of a compact, heterogeneous and tan-colored matrix. Calcite-based regions are located in concentrated areas. Two red coarse-sized aggregates, measuring approximately 0.1 mm, are visibly coated in the lime based material and are distinct from the surrounding matrix. Red and brown fine-sized aggregates of subangular and subrounded shapes are distributed throughout the plaster. A brown vein runs through the center, possibly indicating the presence of iron. No distinct layers are discernible.



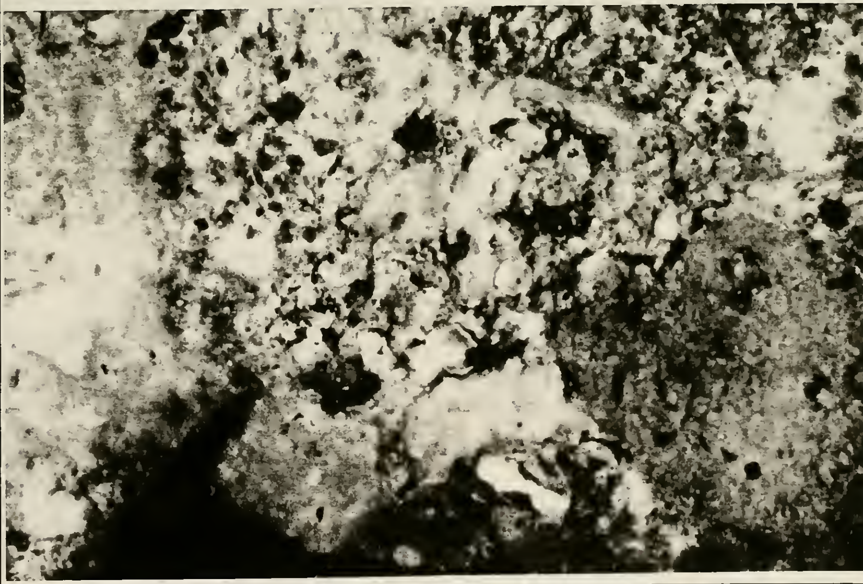
CROSS SECTION EXAMINATION	SAMPLE: 26677

Floor Name: Piso Don Renecito

Sample Location: Rosalila, Tunnel 33. West side, abuts top of 1st step of west stairs.

Division: 2	Date: A.D. 540 - 650	Magnification: 10x

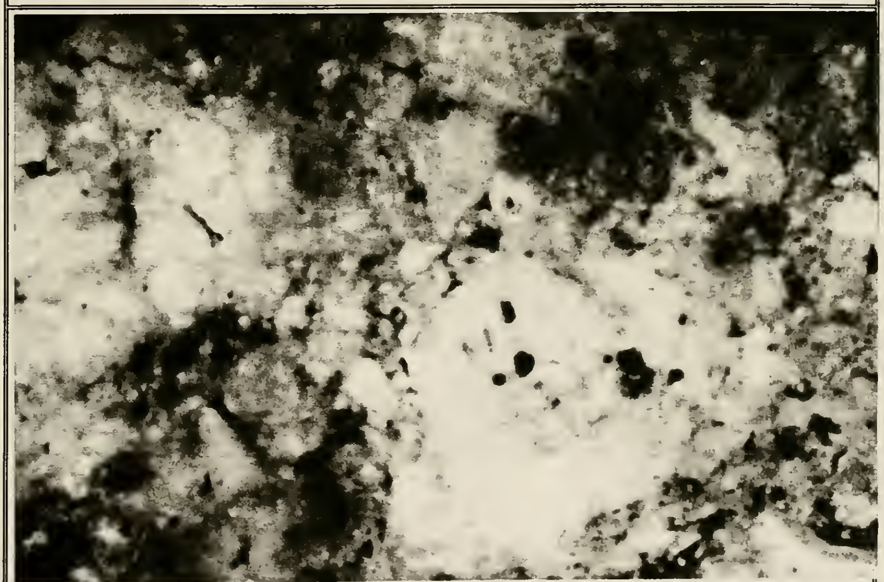
General Description:
Sample consists of a heterogeneous, cream and reddish-brown colored plaster. Calcite-based particles of various sizes are distributed throughout. White and red zones are integrated to obscure the interfaces of the calcite particles from the matrix. A coarse-sized tuff aggregate, measuring 3 mm, contains minterals within its matrix as well as a yellowish cast, likely caused by mineral impurities. Two medium-sized shells are located in the center of the sample. No distinct layers are discernible.



CROSS SECTION EXAMINATION		SAMPLE: 26701
Floor Name: Piso Don Marcos		
Sample Location: Rosalila, interior floor.		
Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

General Description:

Sample consists of a matrix in various shades of cream, white and tan. Heterogeneous in color and texture, it appears as an agglomeration of calcite-based particles, ranging from fine to coarse sizes up to 0.3 mm. Well sorted dark brown, rust, and green particles of subangular shapes punctuate the matrix. A rust-colored cast is concentrated in areas, likely from iron staining. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 26719

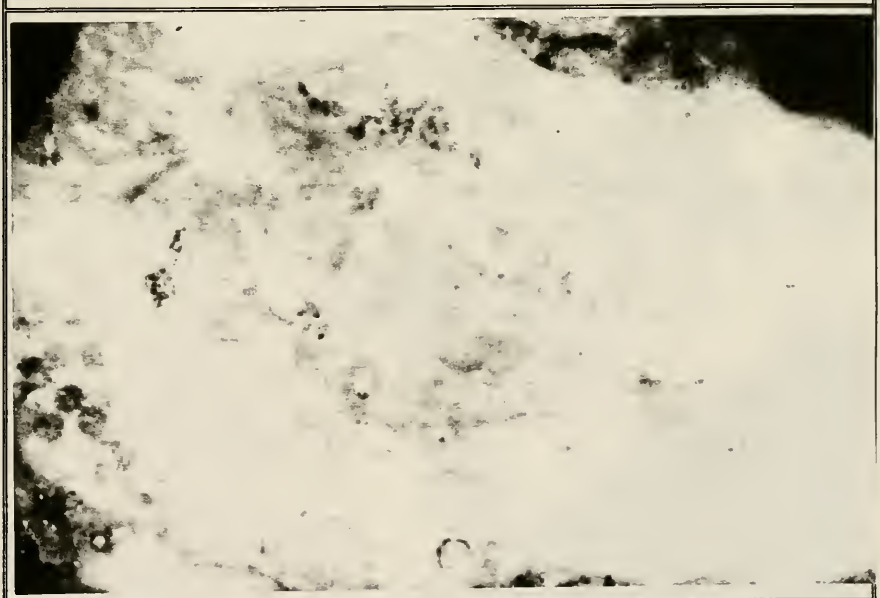
Floor Name: Piso Don Simon

Sample Location: Rosalila, abuts base of Azul.

Division: 2	Date: A.D. 540 - 650	Magnification: 5x

General Description:

Sample consists of a heterogeneous, compact, cream-colored plaster matrix. A few fine-sized brown particles of subrounded and subangular shapes are visible towards the edges. Vacuoles are present, ranging between 0.05 – 0.2 mm, which may have contained medium-sized particles. White spherical shapes as well as larger zones, both of which are lime-based, are distributed throughout the plaster. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 26724

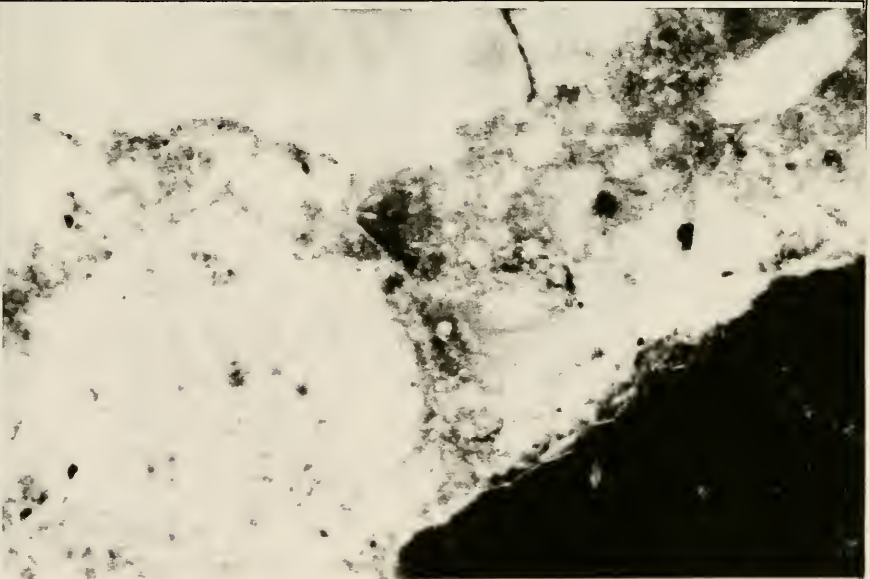
Floor Name: Piso Don Gustavo

Sample Location: Rosalila, runs between Oropendola and Rosalila.

Division: 2	Date: A.D. 540 - 650	Magnification: 7.5x

General Description:

Sample consists of a heterogeneous cream and yellow-colored plaster matrix. Two spherically-shaped zones are distinct in color and texture from the surrounding matrix. The plaster contains calcite-based particles of fine to medium sizes, and rounded and oblong shapes. Also present are fine-sized aggregates of brown, green, yellow, gray and rust colors. At one edge of the plaster is a coarse-sized, subangular gray particle, measuring approximately 0.7 mm. The rust-colored cast likely represents iron stains. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 26725

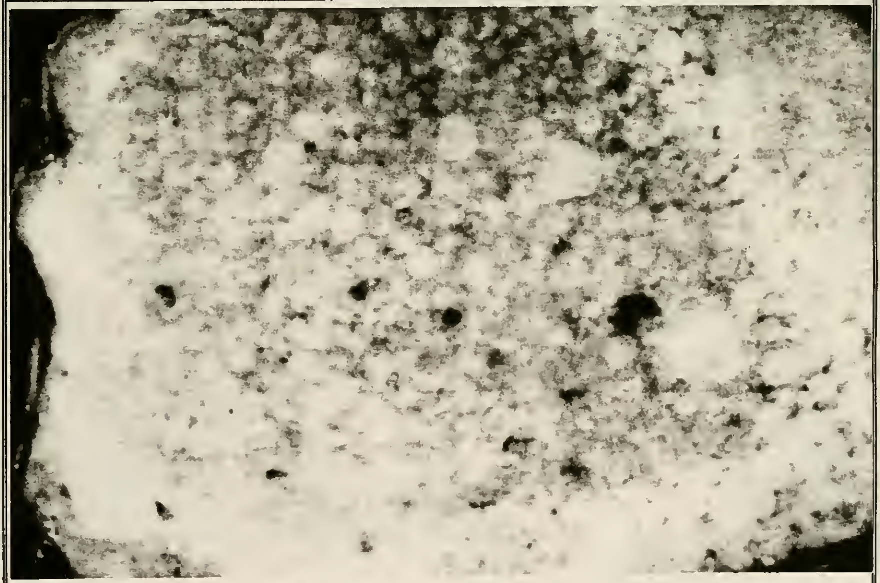
Floor Name: Piso Don Rene

Sample Location: Rosalila, runs over top step of Azul on west side.

Division: 2	Date: A.D. 540 - 650	Magnification: 7.5x

General Description:

Sample consists of a homogeneous, compact, tan-colored plaster. Cream-colored spherically shaped aggregates of fine to medium sizes are densely packed within the matrix which may be calcite-based particles or lime-coated aggregates. Fine-sized brown particles, measuring approximately 0.03 mm, are visible as well. The darker horizon at the edge of the plaster is from the resin penetrating the plaster. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 26733-1

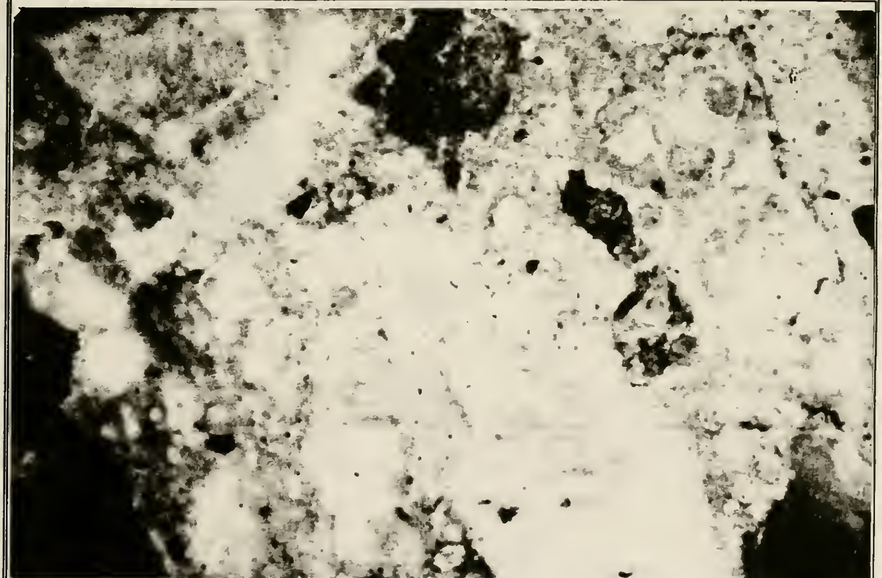
Floor Name: Piso Don Lorenzo

Sample Location: Rosalila, abuts modification of west steps of Azul.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x

General Description:

Sample consists of a heterogeneous, tan-colored plaster matrix. Rounded and subrounded calcite-based aggregates and veins of varying thicknesses are visible throughout. A slight reddish cast of the matrix likely results from particle inclusions. Poorly sorted particles of subangular and subrounded shapes are visible in fine to coarse sizes, ranging between 0.1 and 0.2 mm, of various colors (red, brown, and gray). No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 26733-2	

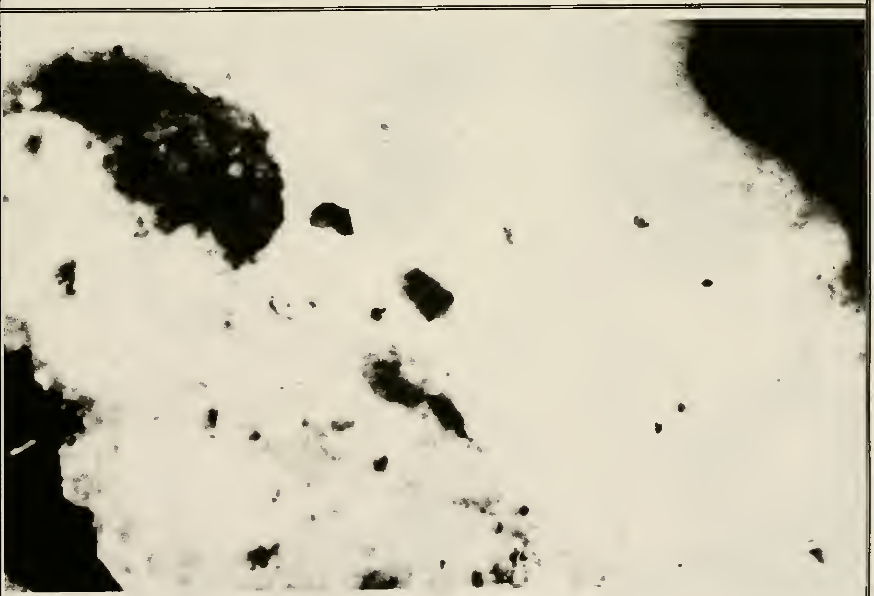
Floor Name: Piso Don Lorencito

Sample Location: Rosalila, abuts the 1st step of the original west steps of Azul.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 10x

General Description:

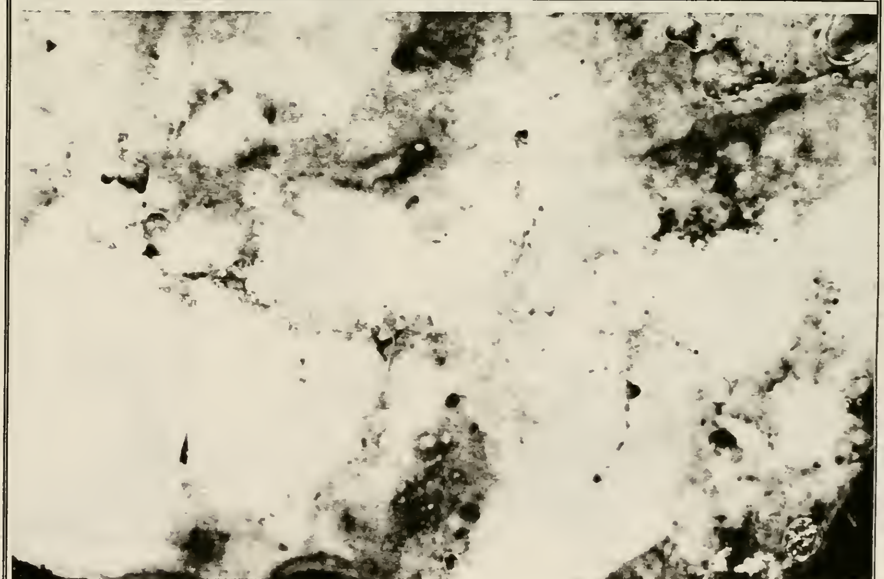
Sample consists of a compact white and cream-colored, homogeneous plaster. Fine to coarse-sized reddish-brown particles, measuring approximately 0.2 mm, of subrounded and subangular shapes are distributed throughout the matrix. Calcite-based particles, ranging from fine subangular shapes to more expansive amorphous regions are difficult to distinguish from the matrix. No distinct layers are discernible.



CROSS SECTION EXAMINATION	SAMPLE: 27304	
Floor Name: Piso Don Lupito		
Sample Location: Rosalila, runs under Azul platform.		
Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

General Description:

Sample consists of a heterogeneous, ivory colored plaster. An agglomeration of lime-based particles, ranging in size from 0.1 – 0.2 mm are visible in the matrix. Their blurred edges make it difficult to distinguish their shapes. Fine-sized particles, up to 0.1 mm, in colors of rust and brown, exhibiting subrounded and subangular shapes are located at several interfaces of the calcareous particles and matrix. No distinct layers are discernible.



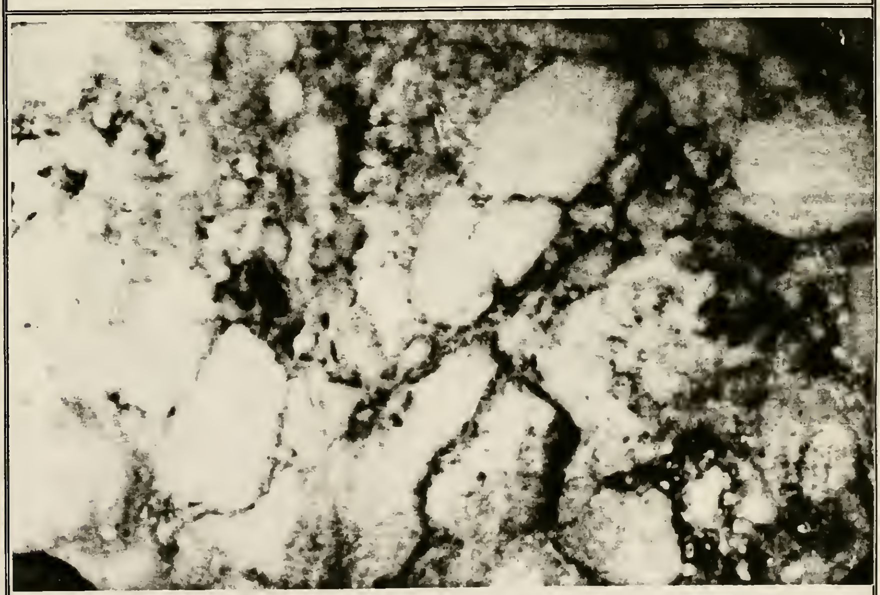
CROSS SECTION EXAMINATION	SAMPLE: 27306

Floor Name: Piso Don Quijana

Sample Location: Rosalila, runs under Celeste.

Division: 2	Date: A.D. 540 - 650	Magnification: 5x

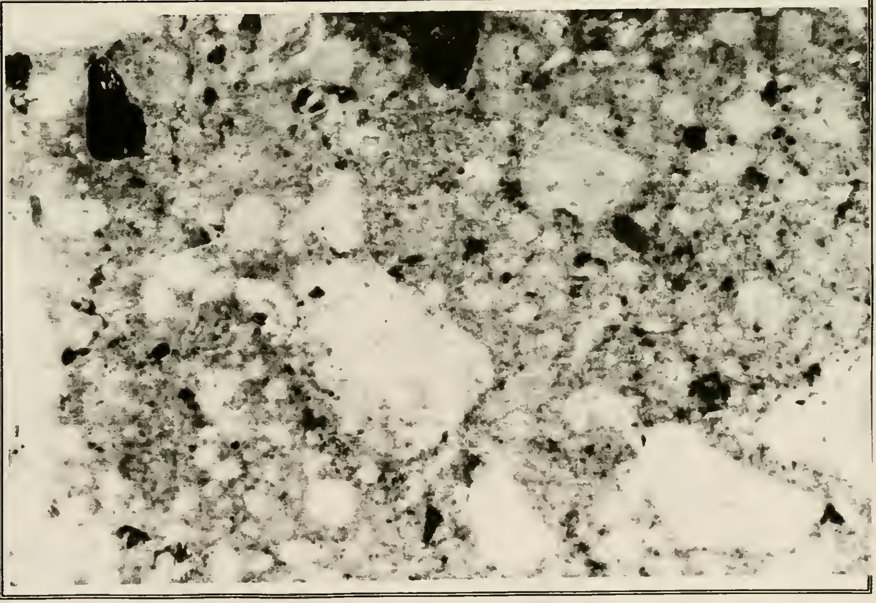
General Description:
Sample consists of a compact, heterogeneous cream-colored matrix. Coarse-sized calcite-based particles, measuring up to 0.3 mm, in subangular shapes are visible in the matrix. Several edges are punctuated by dark brown, fine particles or carbonaceous material. Larger subrounded, dark brown aggregates are also distinguishable. No distinct layers are discernible.



CROSS SECTION EXAMINATION		SAMPLE: 28020
Floor Name: Piso Don Quixote I		
Sample Location: Rosalila, runs under original west stairs.		
Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x

General Description:

Sample consists of a heterogeneous, compact, and tan-colored matrix. Poorly sorted aggregates of various sizes and shapes (rounded, subrounded, and subangular) are visible. Coarse-sized calcite-based particles, up to 0.2 mm, in white and cream are abundant throughout the matrix, followed by fine to medium-sized particles in various colors (black, gray, rust, tan, and green). No distinct layers are discernible.



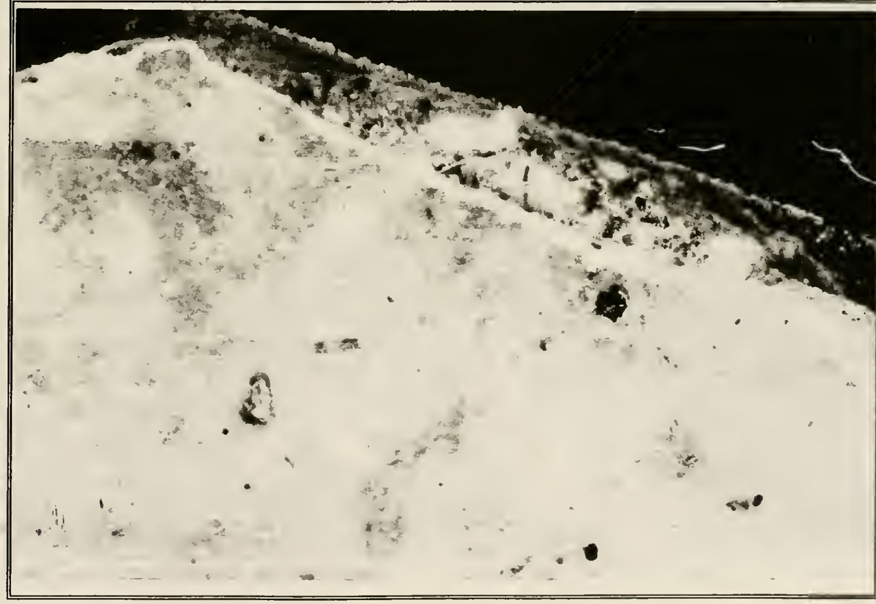
CROSS SECTION EXAMINATION	SAMPLE: 28021

Floor Name: Don Quixote II

Sample Location: Rosalila, Tunnel 33.

Division: 2	Date: A.D. 540 - 650	Magnification: 10x

General Description:
Sample consists of a compact, homogeneous yellow-greenish matrix, most likely representing a volcanic tuff aggregate. The ground layer contains few fine to medium sized particles, up to 0.1 mm of dark bown, translucent, and white colors.
A subsequent layer measuring 0.1 mme, is composed of a thin white layer, most likely a lime wash. The finish layer is dense and consists of fine-sized dark brown and white aggregates.



CROSS SECTION EXAMINATION	SAMPLE: 28024

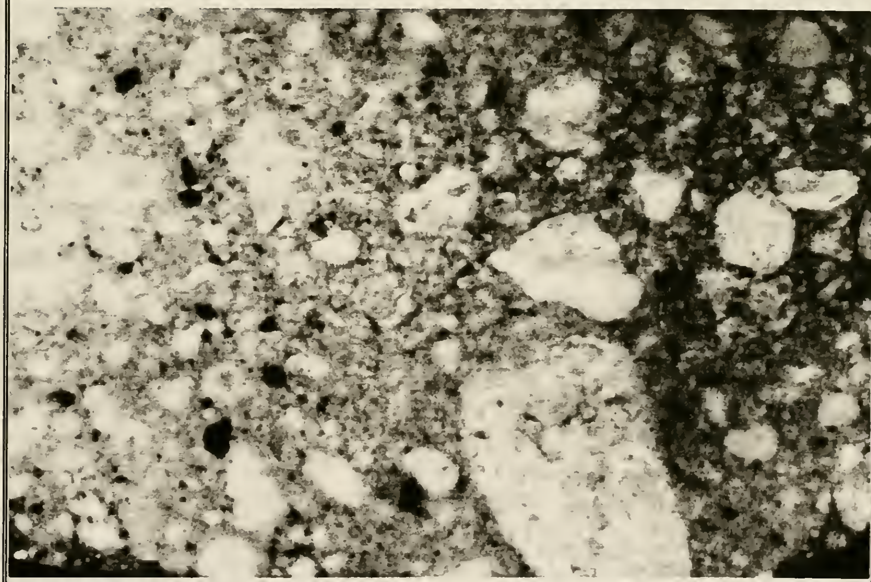
Floor Name: Room 5

Sample Location: Rosalila, Tunnel 34

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

General Description:

Sample consists of a compact, heterogeneous and tan-colored plaster matrix. Calcite-based particles of fine to coarse sizes, ranging from 0.1 to 0.5 mm, of round, subround and subangular shapes are distinguishable from the darker colored matrix. The larger particles consist of various colors (white, ivory, and tan). Various colored aggregates (red, gray, and brown) of subangular and subrounded shapes and fine to medium sizes are distributed throughout. No distinct layers are discernible.



4.2.5 Thin Section Examination

Micromorphological analysis using thin sections revealed that the floors consisted of two distinct types of plaster, an earthen (#37 and 36) and a fine-grained lime plaster (#95, 59, 26 and 26733), based on the way they take up the stain for calcite.

Plaster quality was observed to improve over time as evidenced by the greater proportion of binder to aggregate, in addition to improved aggregate sorting. The earlier earthen plasters displayed a heterogeneous and relatively porous matrix, including voids and cracks. Subsequent lime plasters exhibited greater homogeneity and a microcrystalline or cryptocrystalline matrix indicating a hard and durable cement. Neither the earthen nor lime plasters displayed any discernible layers.

The lime plaster matrices exhibited unidentified amorphic forms in various sizes and elongated, curved or spherical shapes (#26,95, 59, and 26733). They were calcite-based, yet stained in the presence of alizarin red S with varying intensity, possibly due to the presence of clays or a fine-grained quartz. The presence of amorphic forms, which indicates fossilized material, may suggest that the limestone was insufficiently calcined; presumably these shapes would alter beyond recognition in high firing temperatures. Two lime plasters (#26 and #59) both contained fine-grained amorphic forms which did not stain for calcite. However, the unidentified features in the plaster from Division 2 (#59) appeared more regular and defined than those from Division 5 (#26). The source of these shapes is unknown, but presumably it was some type of replacement material, possibly a fine-grained quartz derived from siliceous shells.

The variable shapes and sizes of minerals suggested the aggregates were obtained from different sources. Quartz was the dominant mineral in all samples, followed by feldspar. Throughout all time spans, a metamorphic quartz in subangular and subrounded shapes was observed in both the earthen and lime plasters (#36, 37, 59, and 95). A rare type of quartz, known as a mylenite, characterized by its undulating extinction and

sheared crystals, is useful for petrologists in determining the source of these aggregates.[1] The two remaining samples (#26 and 26733) contained a neglible amount of quartz exhibiting smooth surfaces.

Variations were also apparent in the abundance of aggregates.[2] In the earliest earthen plaster (#37), fine to coarse-sized minerals of rounded, subrounded, angular, and subangular shapes constituted approximately 30% of the matrix. The later earthen sample from Division 5 (#36) consisted of approximately 99% quartz and feldspar minerals of subangular and subrounded shapes, and medium to coarse sizes. The earliest lime plaster (#95), contained approximately 2-5% medium to coarse-sized aggregates of subangular and subrounded shapes. From the same construction phase, a lime plaster (#26) consisted of approximately 2% fine to medium-sized rounded aggregates. A lime plaster from Division 2 (#26733), dating to at least a hundred years later, was composed 1% quartz minerals of subrounded and subangular shapes in medium to coarse sizes. In the same time span, a lime plaster (#59) similiarly contained subrounded and subangular-shaped aggregates of medium to coarse sizes though in greater proportion, comprising approximately 25% of the matrix.

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[1] Gomaa Omar, personal correspondence, 1996.

[2] The percentage of aggregates did not take the calcareous aggregates into account.

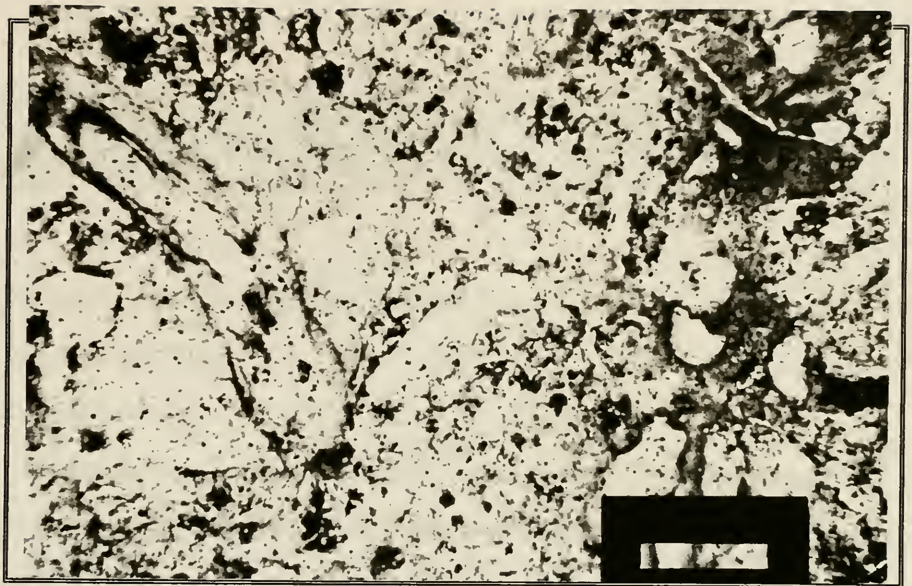
Thin Section Micromorphology

Sample	Fine-Grain Calcite Matrix	% Silica Aggs	Amorphic Shapes in Matrix	Degree of Sorting			Particle Shape						
							Roundness						
				Well	Mod.	Poor	Round	Subround	Angular	Subangular	Smooth	Undulating
37		50				✓	✓	✓	✓	✓	✓	
36		99				✓		✓	✓	✓		✓
95	✓	2	✓	✓			✓	✓	✓	✓	✓	
26	✓	1	✓					✓	✓	✓	✓	
26733	✓	25	✓		✓							
59	✓	1	✓		✓			✓	✓	✓	✓	

THIN SECTION EXAMINATION	SAMPLE: 26
Floor Name: Bernal	
Sample Location: Structure 26, south of Tartan.	
Division: 5, MAS 9	**Date:** A.D. 440 - 450

General Description:

The sample contains a negligible amount of calcareous material which does not exceed 1% as indicated by the absence of staining for calcite. Within its porous and predeominantly iron-stained matrix are inclusions of polycrystalline, medium to coarse-sized quartz particles of subangular, angular and subrounded shapes, and poorly sorted. Under crossed polars, individual crystals display sutured boundaries, indicating the quartz is from a metamorphic source, possibly mylenite, . Another zone contains sheared and elongated quartz crystals, oriented in a preferred direction, also indicating a metamorphic origin. No distinct layers are discernible



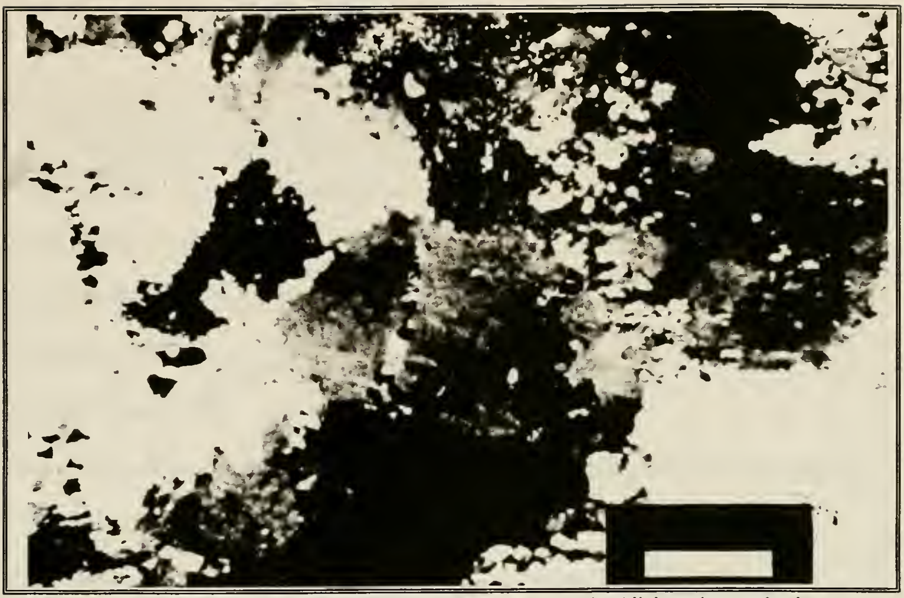
Photomicrograph of thin section #26 (Division 5) at 25x under transmitted light and crossed polars.

Photomicrograph of thin section #26 (Division 5) at 25x under transmitted light and crossed polars.

THIN SECTION EXAMINATION	SAMPLE: 36
Floor Name: Papo	
Sample Location: Northeast Court Group, below Loro.	
Division: 5, MAS 11	**Date:** A.D. 480 - 520

General Description:

The sample contains a negligible amount of calcareous material which does not exceed 1%, as indicated by the absence of staining for calcite. Within its porous and predeominantly iron-stained matrix are inclusions of polycrystalline, medium to coarse-sized quartz particles of subangular, angular and subrounded shapes, and poorly sorted. Under crossed polars, individual crystals display sutured boundaries, indicating the quartz is from a metamorphic source, possibly mylenite, . Another zone contains sheared and elongated quartz crystals, oriented in a preferred direction, also indicating a metamorphic origin. No distinct layers are discernible.



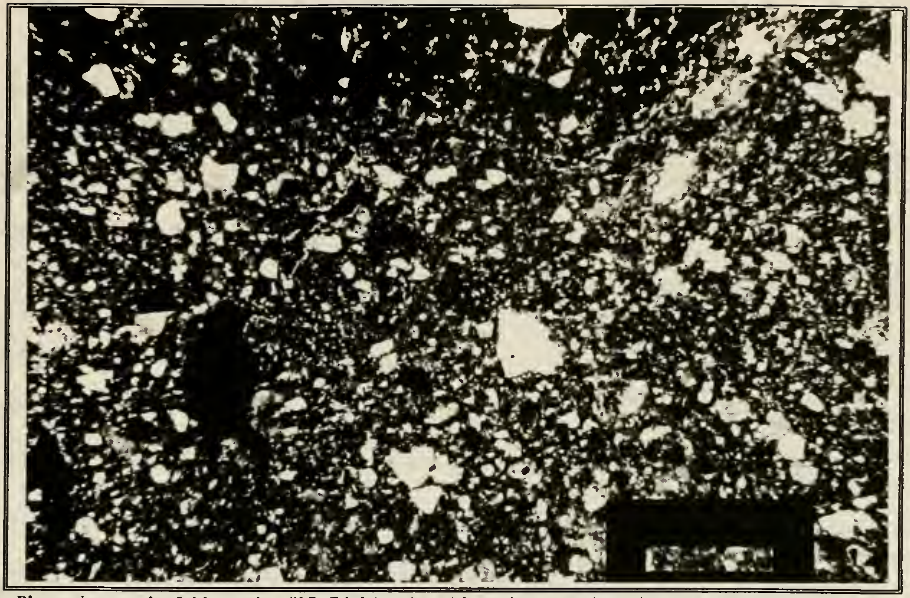
Photomicrograph of thin section #36 (Division 5) at 25x under transmitted light and crossed polars.

Photomicrograph of thin section #36 (Division 5) at 25x under transmitted light and crossed polars.

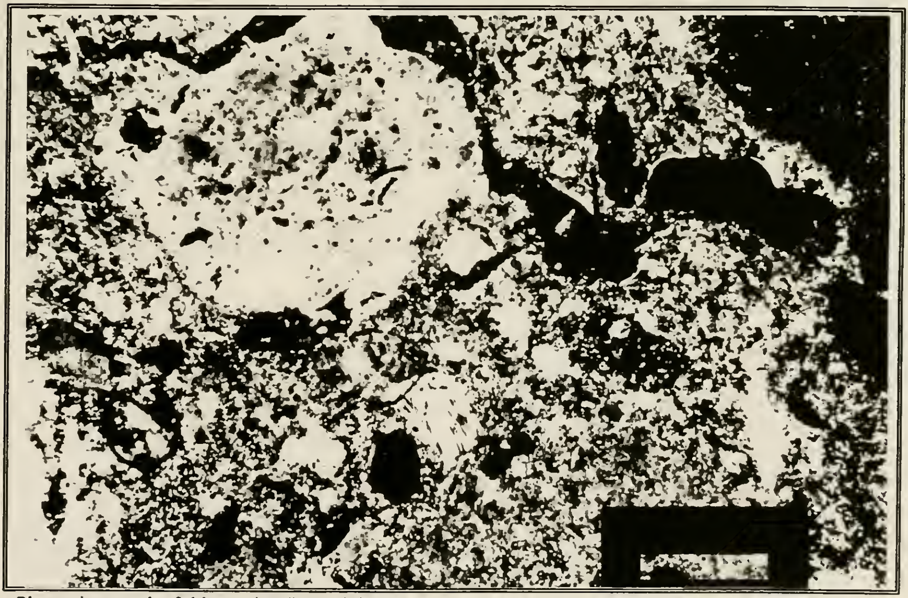
THIN SECTION EXAMINATION	SAMPLE: 36
Floor Name: Papo	
Sample Location: Northeast Court Group, below Loro.	
Division: 5, MAS 11	**Date:** A.D. 480 - 520

General Description:

The sample contains a negligible amount of calcareous material which does not exceed 1%, as indicated by the absence of staining for calcite. Within its porous and predeominantly iron-stained matrix are inclusions of polycrystalline, medium to coarse-sized quartz particles of subangular, angular and subrounded shapes, and poorly sorted. Under crossed polars, individual crystals display sutured boundaries, indicating the quartz is from a metamorphic source, possibly mylenite, . Another zone contains sheared and elongated quartz crystals, oriented in a preferred direction, also indicating a metamorphic origin. No distinct layers are discernible.



Photomicrograph of thin section #37 (Division 6) at 25x under transmitted light and crossed polars.



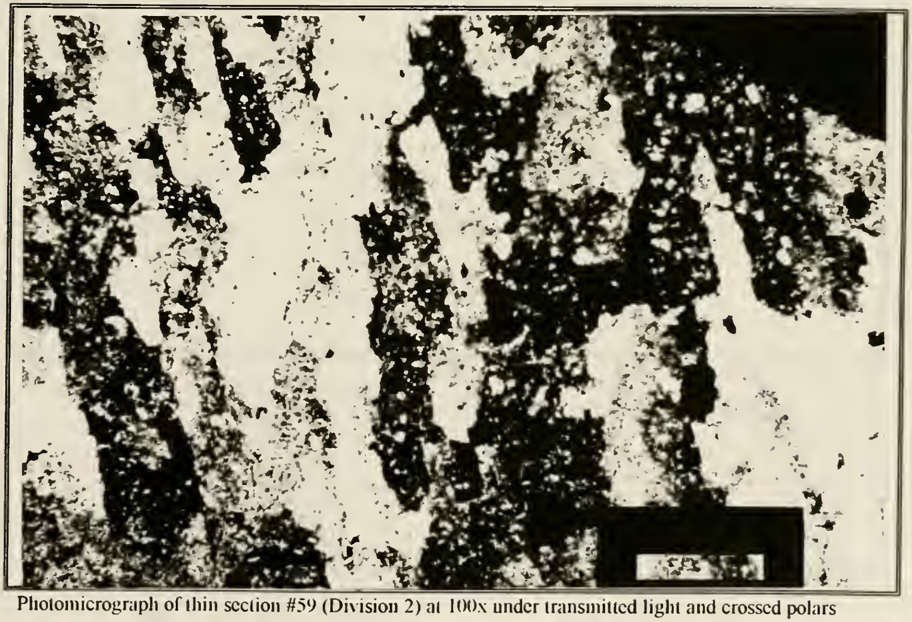
Photomicrograph of thin section #37 (Division 6) at 25x under transmitted light and crossed polars.

THIN SECTION EXAMINATION	SAMPLE: 59
Floor Name: Chachalaca Floor #1	
Sample Location: Northeast Court Group, abuts east side. Last plaza floor surface.	
Division: 2	**Date:** A.D. 540 - 650

General Description:

Sample consists of a fine-grained calcareous matrix containing approximately 25% fine to coarse-sized quartz and few feldspar particles. They are moderately sorted and of subrounded and subangular shapes. Sheared metamorphic quartz particles display undulating surfaces. Unidentified amorphous features of rounded and elongated shapes do not take up the stain for calcite. It may be replacement material representing a fine-grained quartz. Approximately 2% is carbonaceous material, indicated by the black-colored isotropic regions. No distinct layers are discernible.

Photomicrograph of thin section #59 (Division 2) at 100x under transmitted light and crossed polars.



Photomicrograph of thin section #59 (Division 2) at 100x under transmitted light and crossed polars

THIN SECTION EXAMINATION	SAMPLE: 95
Floor Name: Asmen	
Sample Location: MAS, west of Margarita, below Tuna.	
Division: 5, MAS 9	**Date:** A.D. 440 – 450

General Description:

Sample consists of a fine particle matrix which stains positively for calcite, though of lesser intensity compared to other samples, possibly indicating a higher proportion of clays. It is heavily stained with iron, particularly along crack lines and at the interfaces of individual minerals.

It contains a negligible amount of fine-sized, moderately sorted quartz particles, approximately 2%, which are of subangular and subrounded shapes with smooth surfaces. Several of the quartz particles are an agglomeration of honeycomb shaped crystals, which is an unusual characteristic. Unidentified fine to coarse-sized isotropic particles of spherical shapes do not stain positively for calcite. No distinct layers are discernible.

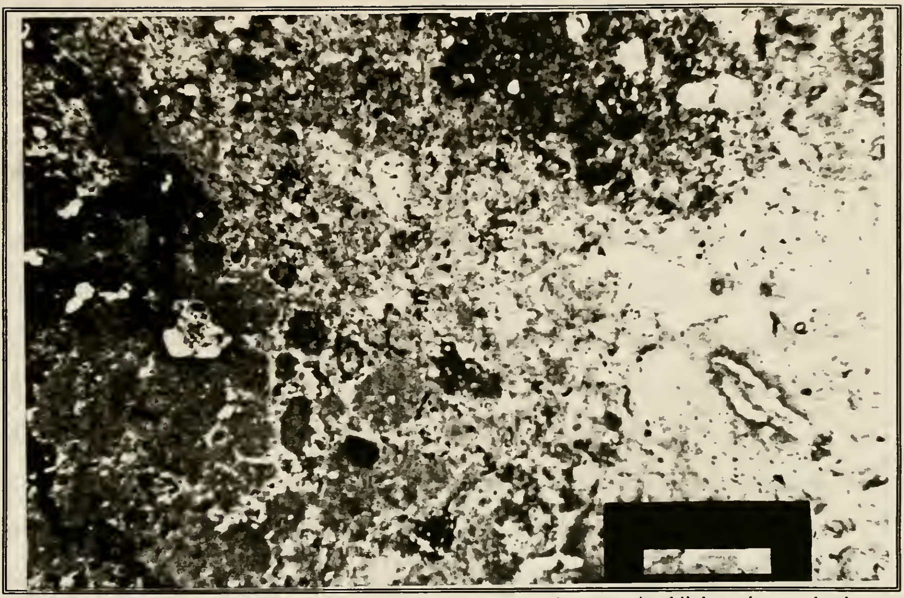
Photomicrograph of thin section #95 (Division 5) at 100x under transmitted light and crossed polars.

Photomicrograph of thin section #95 (Division 5) at 100x under transmitted light and crossed polars.

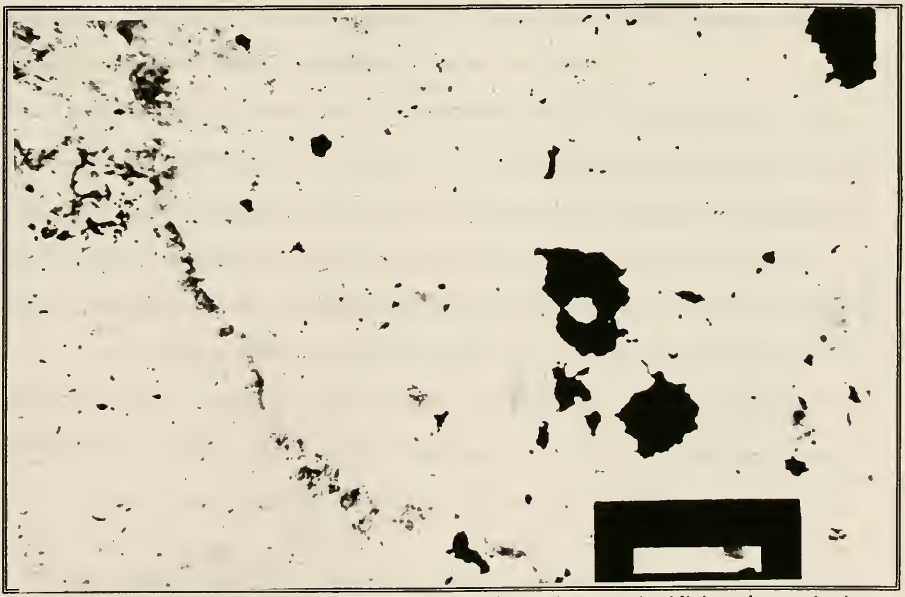
THIN SECTION EXAMINATION	SAMPLE: 26733-1
Floor Name: Piso Don Lorenzo	
Sample Location: Rosalila, abuts modified west steps of Azul.	
Division: 2	**Date:** A.D. 540 - 650

General Description:

Sample consists of a fine-grained, compact calcareous matrix containing approximately 1% quartz and feldspar particles in subangular shapes with smooth surfaces. They range from medium to coarse sizes and are moderately sorted. Masses of unidentified isotropic features of oblong and spherical shapes punctuate the matrix, which may indicate sascab or limestone fragments. Isotropic brown stains, most likely derive from iron oxides. A few black veins occur throughout the sample. No distinct layers are discernible.



Photomicrograph of thin section #26733-1 (Division 2) at 25x under transmitted light and crossed polars.



Photomicrograph of thin section #26733-1 (Division 2) at 25x under transmitted light and crossed polars.

4.2.6 Scanning Electron Microscopy with Energy Dispersive Spectroscopy

The elemental profile of the various samples confirmed the findings of the visual characteristics in the cross sections and thin sections. One earthen plaster (#37) contained a high proportion of silicon, with lesser amounts of aluminum and potassium, elements commonly found in soil. The presence of calcium represented the inclusion of limestone fragments serving as aggregates. Poorly sorted aggregates of rounded, subrounded, angular and subangular shapes were also visible in the matrix. The earthen plaster (#36) from higher in the sequence displayed not only a high percentage of silicon, but also aluminum which may represent a higher clay content.[3]

The four remaining samples were confirmed to be lime plasters, as indicated by the high proportion of calcium. Traces of silicon and iron elements were present in all samples in similiar proportions. One exception, a sample (#26) from Division 5, contained the greatest proportion of silicon which corresponds to the greater proportion of aggregates shown in the photomicrograph than other plasters. Visible aggregates were poorly sorted and of rounded, subrounded, and angular shapes.[4]

One sample (#95) from Division 5 displayed spherically-shaped particles similiar to those in a sample (#26733) from Division 2. At 3,000x magnification, fine-sized calcitic particles in angular, subangular, and subrounded shapes were discernible. The elemental profile reflected of a high percentage of calcium with aluminum, silicon, oxygen (clay), silicon, aluminum, iron and a relatively high proportion of potassium (potassium feldspar).

A sample (#59) from the latest time span, Division 2, revealed a homogeneous matrix in which its aggregate inclusions were barely discernible. The elemental profile indicated an extremely high proportion of calcium relative to the other elements present, such as aluminum, silicon, potassium and iron. Higher in the sequence, a sample (#63)

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[3] The high percentage of gold is attributed to the gold coating on the surface.

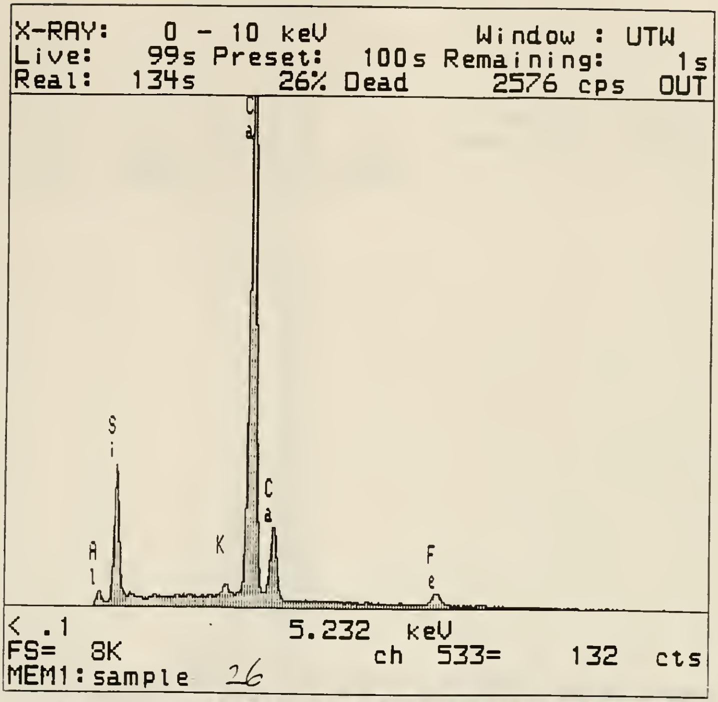
[4] It is difficult to discern at this magnification which individual aggregates are quartz or calcium-based.

displayed its finish layer in the photomicrograph, revealing fine particles of angular, subangular, and subrounded shapes. As expected, there was a high percentage of silicon and oxygen (quartz) with aluminum, silicon, and oxygen (clay) in addition to the calcium content.

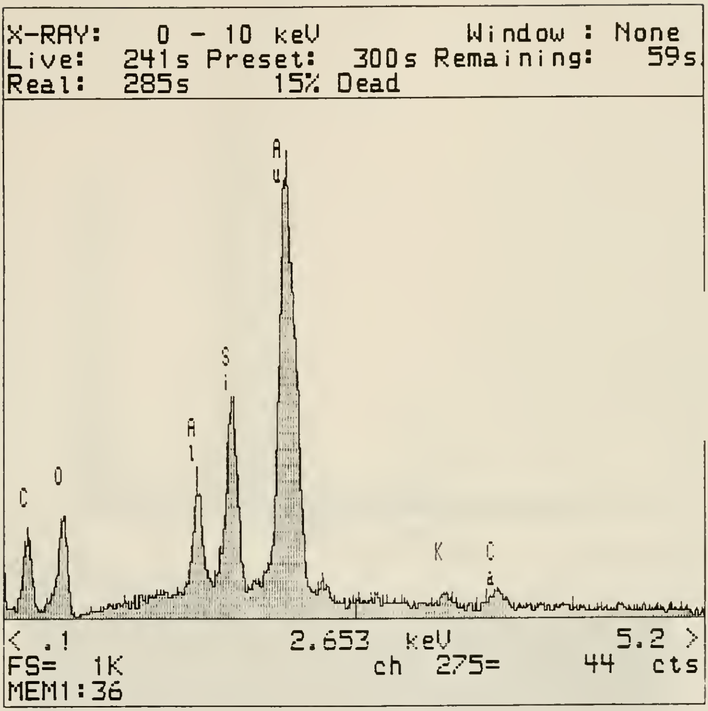
An agglomeration of calcium-based particles, ranging from fine to coarse sizes, were present in the fine-grained lime matrix of one sample (#26733) from Division 2. Some particles displayed textures and interfaces which are distinct from the matrix, while others are more blurred, possibly indicating either primary or recrystallized calcite, or perhaps insufficiently calcined lime. The elemental profile exhibited a high percentage of calcium, with elements such as silicon and oxygen (quartz), aluminum, silicon and oxygen (clay) and trace elements of iron, chlorine and potassium.

Representative samples were coated with gold to obtain the percentage of carbon present. This was to determine whether or not organic (carbon-based) materials, such as bark extracts, were present in the plasters. Three plasters were chosen, a sample which exhibited a red-colored matrix (#59), another with a brown-colored finish layer (#63), and one control sample (#95) which resembled most of the lime plasters examined. In addition, energy dispersive spectroscopy (EDS) mapping analysis was performed on one sample (#63) as a supplemental measure to determine whether the distribution of carbon and oxygen indicated the presence of organic material. Carbon was present in all three samples but not to the degree which would indicate the presence of an organic material. Its presence in the spectra was likely a reflection of the embedding resin.

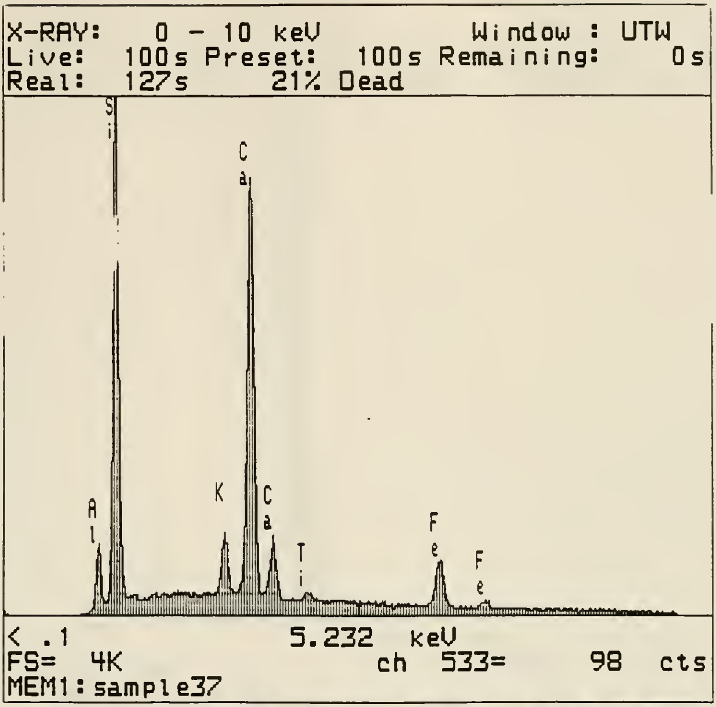
SAMPLE #26 (DIVISION 5)

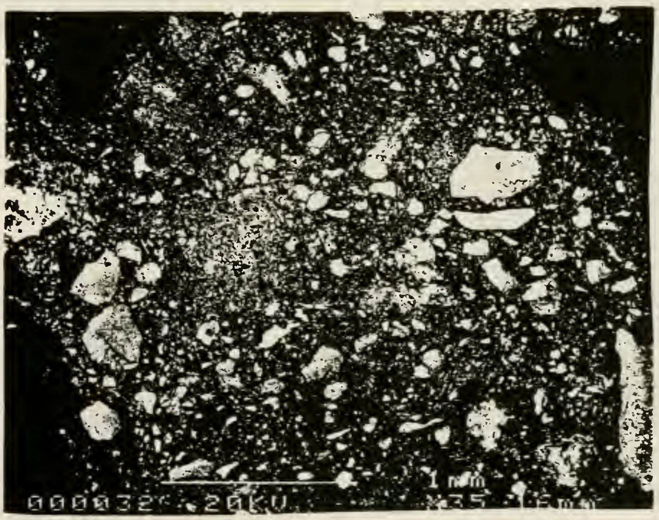


SAMPLE #36 (DIVISION 5)

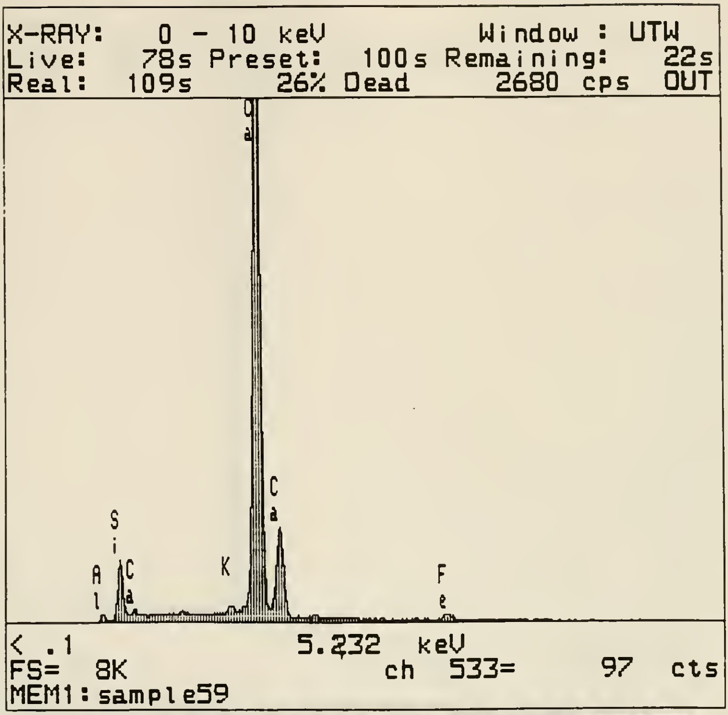


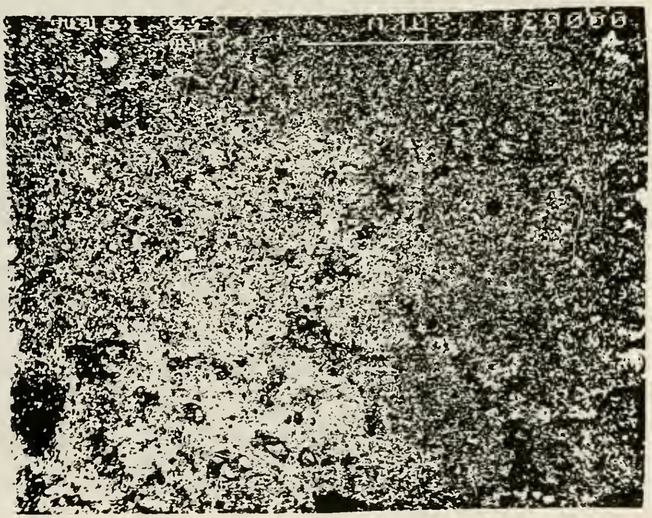
SAMPLE #37 (DIVISION 6)



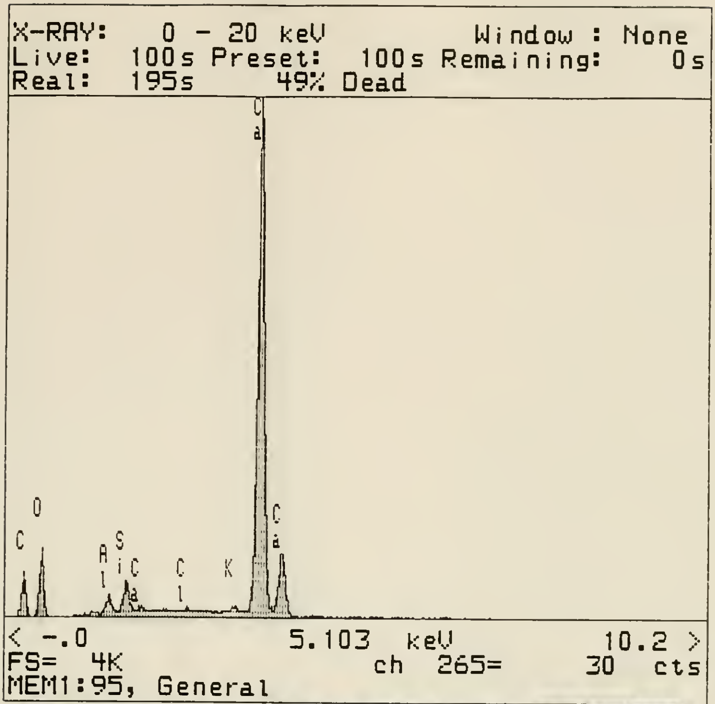


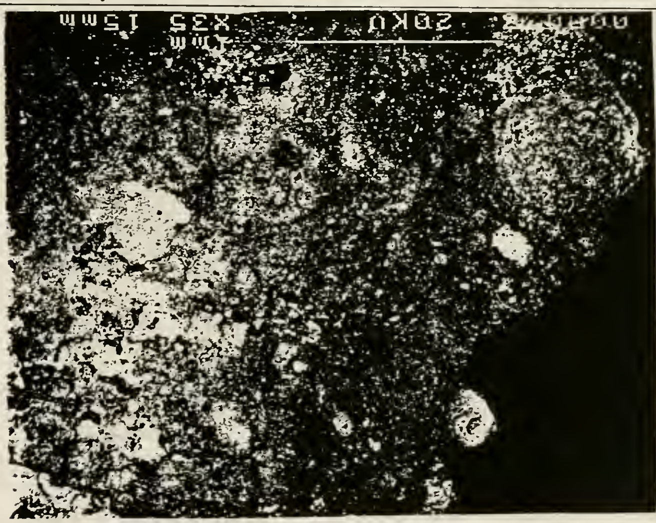
SAMPLE #59 (DIVISION 2)



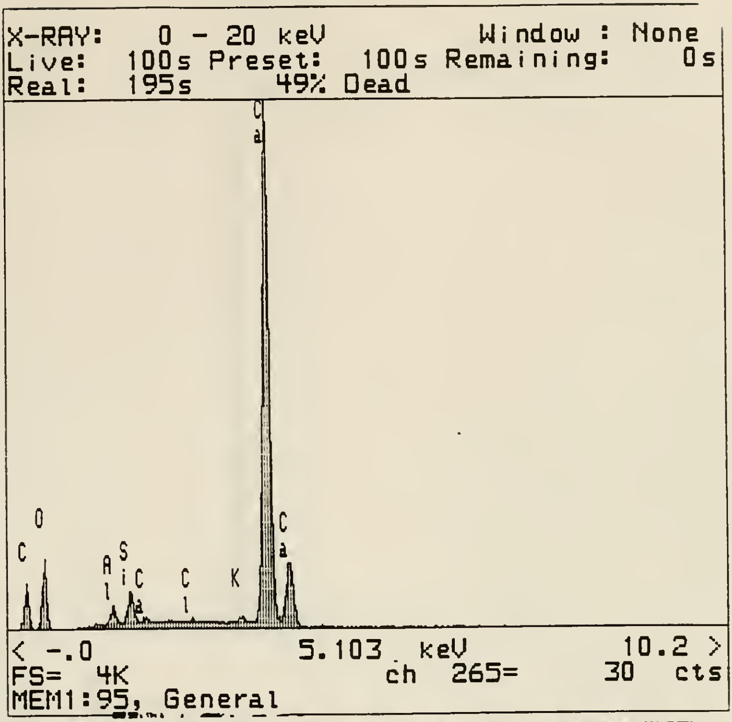


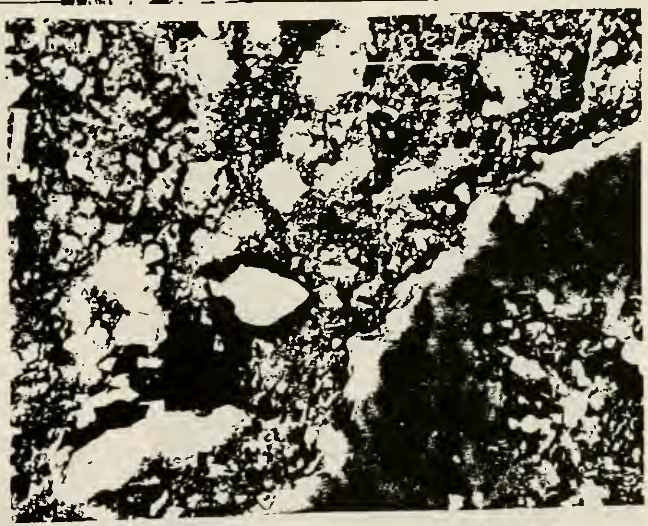
SAMPLE #95 (DIVISION 5)



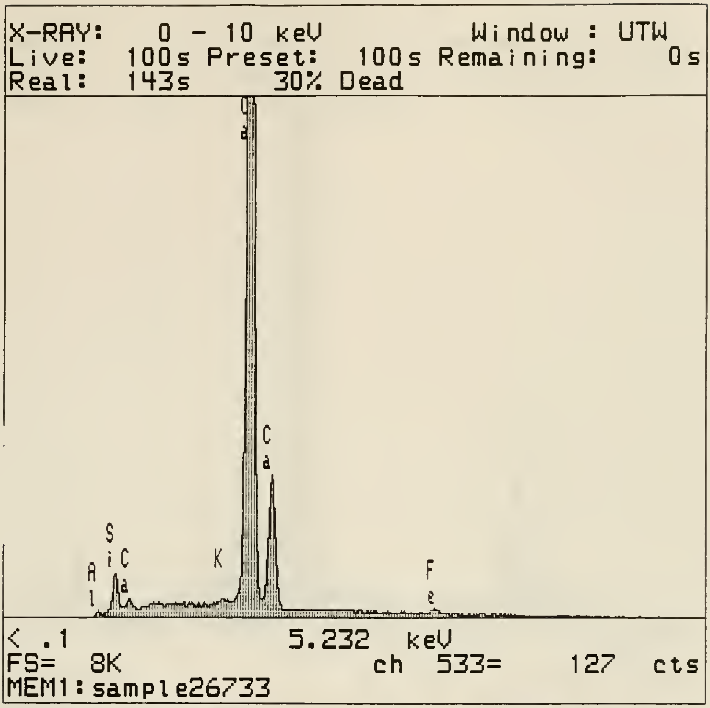


SAMPLE #95 (DIVISION 5)

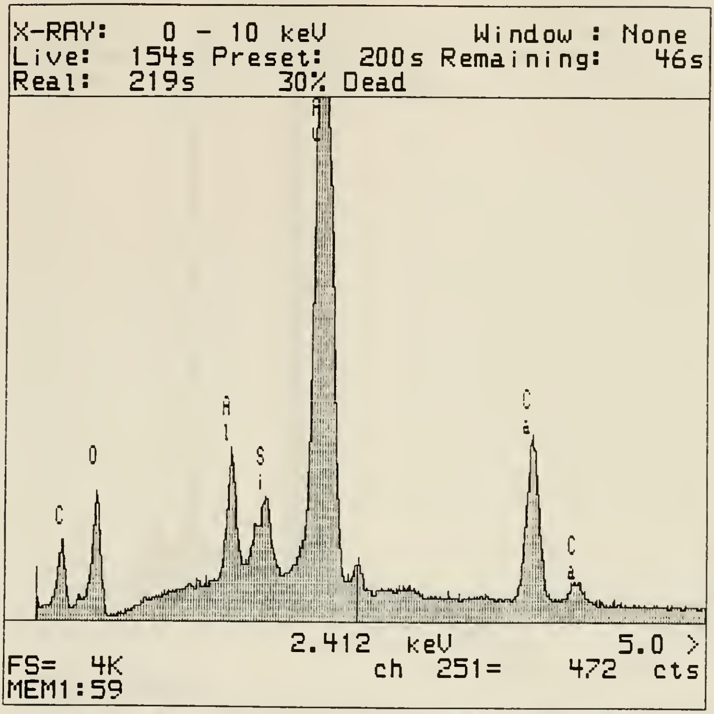


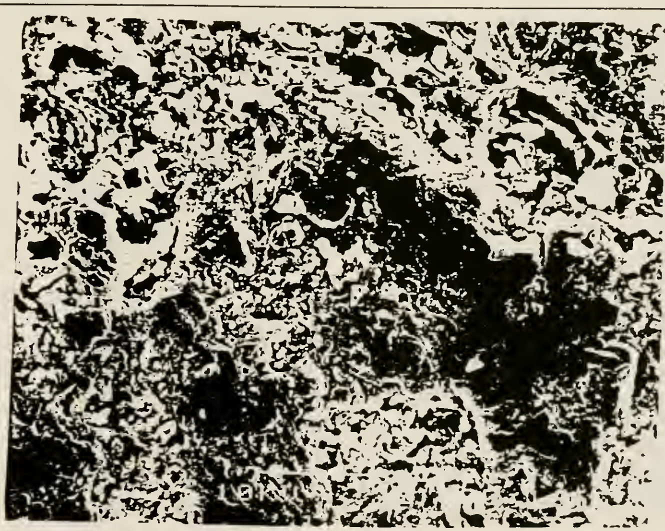


SAMPLE #26733-1 (DIVISION 2)

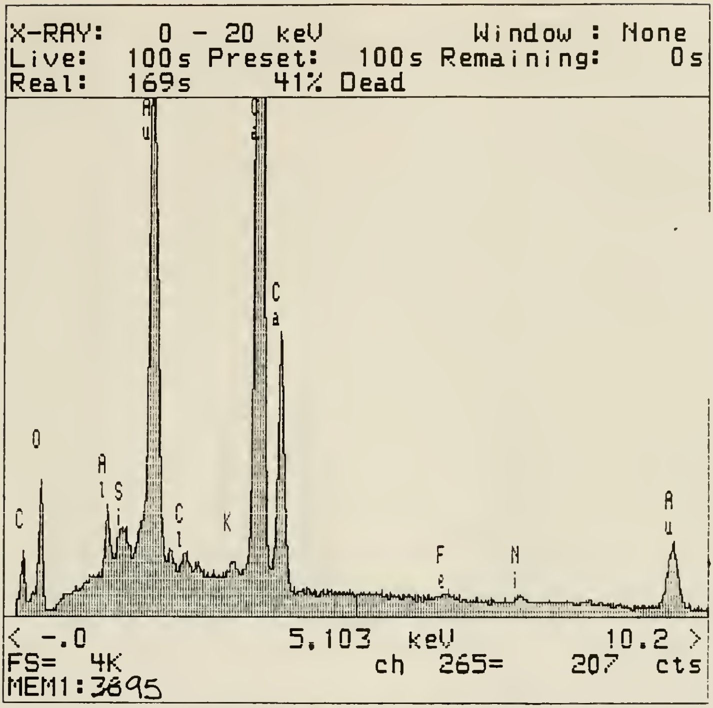


SAMPLE #59 (DIVISION 2) GOLD COATED

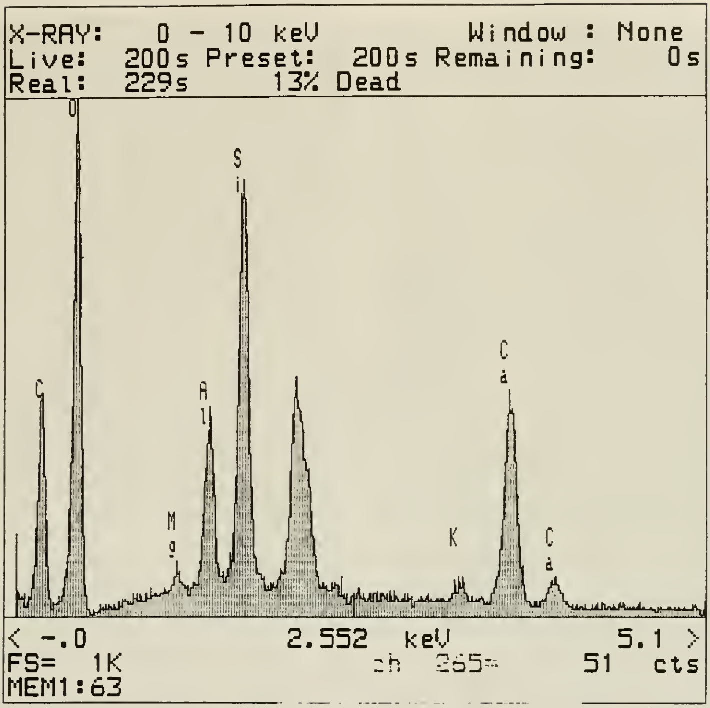


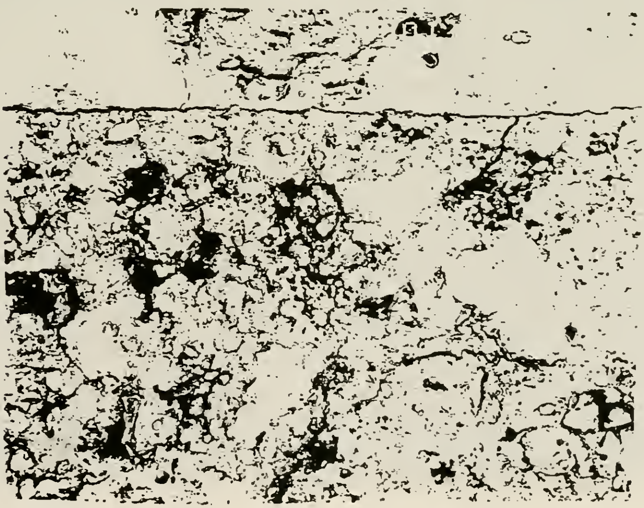


SAMPLE #95 (DIVISION 5) GOLD COATED



SAMPLE #63 (DIVISION 2)





SAMPLE #63 (DIVISION 2)
ENERGY DISPERSIVE SPECTROSCOPY MAPPING ANALYSIS

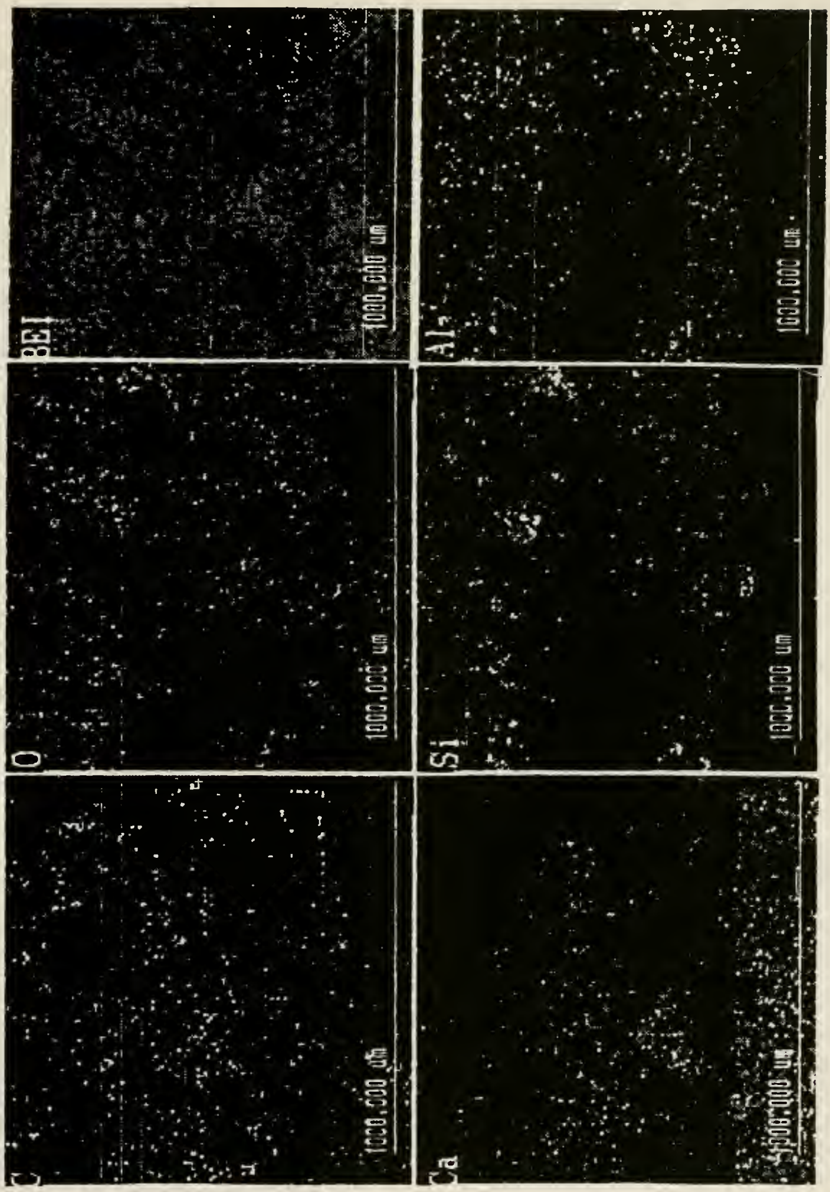


Image: Result sheet. LUT.: Digipad result sheet.
16 grey levels - fine.TYPE: Monochrome.

4.2.7 Wet Chemical Analysis

Wet chemical analysis was performed on all study samples. As expected, the lime plasters were observed to contain a high proportion of calcium carbonate material, either in the form of lime or limestone aggregates.[160] Since the hydrochloric acid digested both materials simultaneously, it was impossible to quantitatively determine the proportions of the binder and the calcareous aggregate.

Division 6: Samples were represented by one earthen (#36) and one lime plaster (#101). Not surprisingly, their ratios of binder to aggregate content were inversely proportioned to each other. With a calcareous content exceeding 90%, the lime plaster (#101) exhibited one of the highest proportions of the samples included in the study.

Division 5: Plasters shared a relatively low percentage of acid-insoluble aggregates in common, averaging approximately 5%, suggesting the majority of the plasters were composed of calcined lime or limestone fragments. Division 5 samples from MAS 11, included three samples, one earthen and two lime plasters. The earthen plaster (#36) from this construction phase contained more calcareous material (approximately 37%) than that of the preceding Division. The lime plasters (#83 and #84) shared similar proportions of calcium carbonate, approximately 88%. Later in MAS 10, several samples consisted of varying amounts of calcareous material, ranging from approximately 65% - 93%. Generally, the sand content was below 4% and fine fraction under 15%. MAS 9 samples exhibited a relative consistency in the proportion of calcareous material, ranging between 80% - 90%, and slightly varied in their sand content, averaging approximately 4%. The calcareous material found in the plasters from MAS 7 ranged between 52% -

[160] High calcium limestone dissolves in most strong acids, while dolomitic limestone will not effervesce unless the weak hydrochloric acid is heated since it is not as reactive. Further, there is a slight difference in the rate of reactivity with high calcium stones depending on the impurities present and to a lesser extent on the porosity and crystal size. High levels of impurities and large crystals retard reactivity; Boynton, Ibid: 30.

During this construction phase, one plaster (#80) consisted of approximately 28% sand content, the largest amount of all Division 5 samples.

Division 4: Similiar to the preceding construction phases, the samples revealed a medium to high proportion of calcareous material, ranging between 68% - 93%, and a consistently low sand content, not exceeding 4%. The proportion of fines exhibited a greater disparity, ranging between 6% - 28%.

Division 2: The majority of samples represented plaster floors from two buildings, Chachalaca, located in NEC, and Rosalila in MAS. Similiar to the pattern observed in Divisions 6 through 4, the content of calcareous material and sand continued to vary in this division. Chachalaca plasters contained a variable calcium carbonate content, ranging between 41% - 86%, and sand, which was absent in one sample (#40), comprised 41% in another (#53). Likewise, the calcareous fraction of the Rosalila plasters ranged between 44% - 94%; the higher figure is from a plaster (#26725) which contained less than 1% acid-insoluble sand content. Hence, it is expected that plasters representing similiar ratios contained a relatively high proportion of calcite-based particles.

Gravimetric Analysis Results			
Sample	**% Acid soluble**	**% Sand**	**% Fines**
Division 6			
37	5.37	84.64	9.99
101	93.62	2.83	3.54
Division 5			
36	37.16	60.13	2.71
83	99.91	2.49	8.6
84	88.03	0.58	11.39
95	85.24	1.42	13.34
96	65.28	9.28	25.46
97	93.04	0.71	6.25
98	89.73	0.83	9.44
99	80.22	4.94	14.84
82	90.23	1.34	8.43
107	85.77	2.73	11.5
105	83.87	3.35	12.78
27	52.46	13.41	34.13
26	80.84	9.3	9.86
38	78.58	6.88	14.54
81	83.66	4.39	11.95
80	60.47	28.41	11.12
88	87.75	2.09	10.16
89	82.21	4.13	13.66
90	86.99	0.93	12.08
Division 4			
28	78.39	4.46	17.15
34	84.75	.48	14.77
35	68.25	3.5	28.25
58	93.37	0.36	6.27

Gravimetric Analysis Results			
Sample	**% Acid Insoluble**	**% Sand**	**% Fines**
Division 2			
67	50.36	24.38	25.26
40	86.53	0	13.46
53	41.14	41.2	17.65
54	46.66	39.85	13.49
64	68.5	14.6	16.94
63	49.84	28.79	21.37
62	56.22	7.8	35.97
61	62.74	19.22	18.04
60	51.9	21.8	27.3
59	85.26	2.47	12.27
65	74.61	10.25	15.14
70	78.26	4.59	17.15
71	63.88	24.73	11.39
72	65.18	25.53	9.29
77	67.61	18.1	14.29
28020	83.55	7.52	8.93
28021	67.42	25.27	7.31
27306	43.57	24.41	32.02
26733-1	47.94	40.34	11.75
26733-2	77.78	8.87	13.34
27304	83.59	5.83	10.58
26677	80.94	5.73	13.32
26724	59.17	31.05	9.78
26719	93.17	0	6.83
25150	72.21	11.61	12.18
26701	88.47	2.67	0.86
26725	94.21	0.4	5.39
28024	44.23	46.83	8.94

4.2.8 Particle Size Distribution

Most samples were observed to contain only a small proportion of silica sand, suggesting the mixture was strengthened by the inclusion of limestone fragments which had been previously dissolved by acid. The size gradients of the remaining particles were found to widely vary and lack any discernible pattern either synchronically or diachronically. However, one shared feature was the size variations in the coarse-sized particles.[6]

Division 6: Plasters contained mostly coarse-sized aggregates. Sand particles greater than 2.36 mm were found in a sample (#37) from NECG to exceed 90%, and 75% in a sample (#101) from the MAS area. Further, the fine sized-particles under 300 µm were either absent (#101), or did not exceed 5% (#37).

Division 5: MAS 11 samples exhibited an inconsistency in overall grading. A sample (#36) from NECG, superimposed on #37 from Division 6, maintained the high proportion of coarse-sized particles, of which 80% exceeded 2.36 mm. A sample (#83) from MAS on the other hand, displayed a more even distribution throughout all size ranges, with coarse-sized particles in the 40% range.

All MAS 10, samples were obtained from the MAS area. On the north side of the Margarita structure, two samples (#84 and 85) contained particles only within the 75 µm and 1.18 mm range, albeit in dissimilar proportions. The remaining samples from the west side shared a relatively well proportion particle size distribution in common.

The MAS 7 samples displayed markedly different size gradients, exhibiting coarse-sized particles to vary between 0 - 80% of the total weight. In the NECG samples, the particle sizes were more evenly distributed, except for a plaster (#38) which contained over 75% of its siliceous aggregate weight in sizes greater than 2.36 mm.

[6] Because the size of the samples used for the gravimetric procedure was relatively low, the results obtained in this analysis are inconclusive, particularly in terms of the relative proportions of coarse-sized particles.

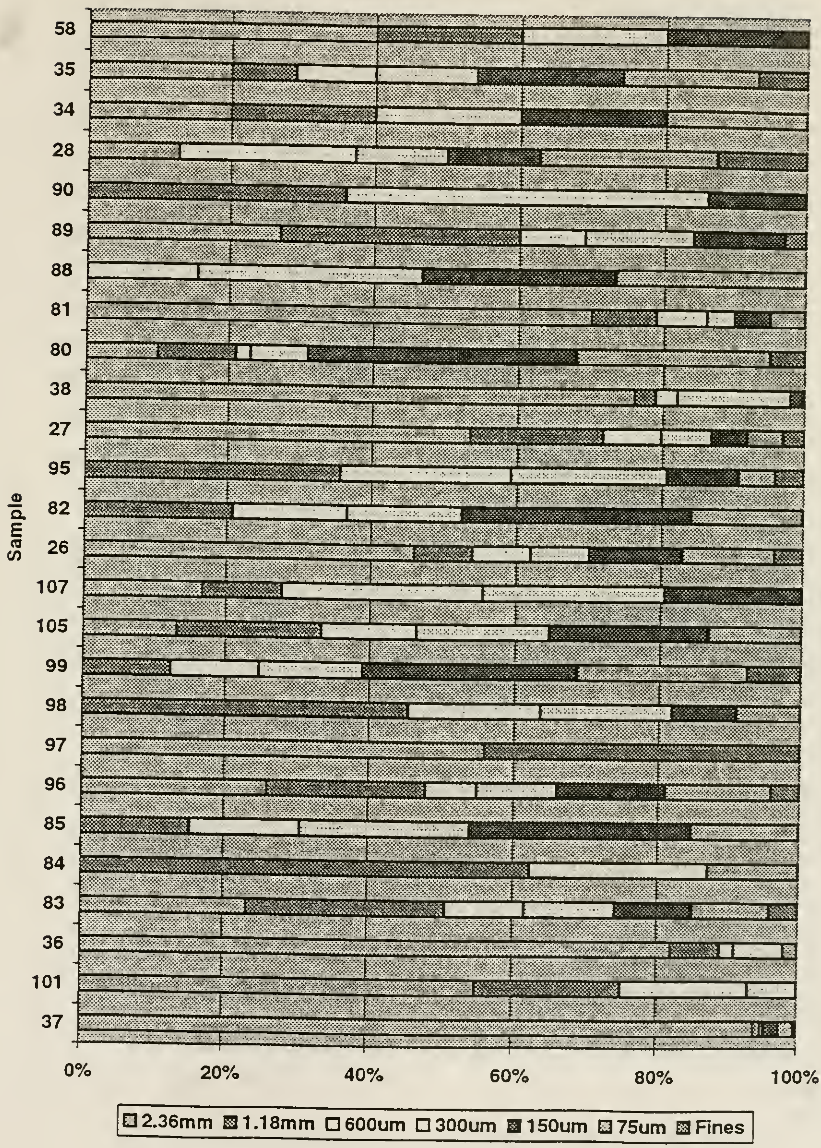
Division 4: The samples, all collected from the NECG area, were found to exhibit the most consistent size distribution throughout one time span. Each particle size under 2.36 mm averaged approximately 15% of the total weight. Not surprisingly, particles above 2.36 mm exhibited a greater variation, from 12% up to 40%, since the presence of a few particles would make a significant difference in weight.

Division 2: All samples obtained from the NECG and MAS areas displayed considerably disparate size gradients. Plasters from Chachalaca for example, exhibited particle sizes larger than 2.36 mm to range between 0 - 80%. The same was true of plasters found in Rosalila and other NECG buildings. In the fine particle sizes however, a greater consistency was observed, in that all particles under 1.18 mm did not exceed 33% of the total weight, except for a Rosalila plaster (#26725).

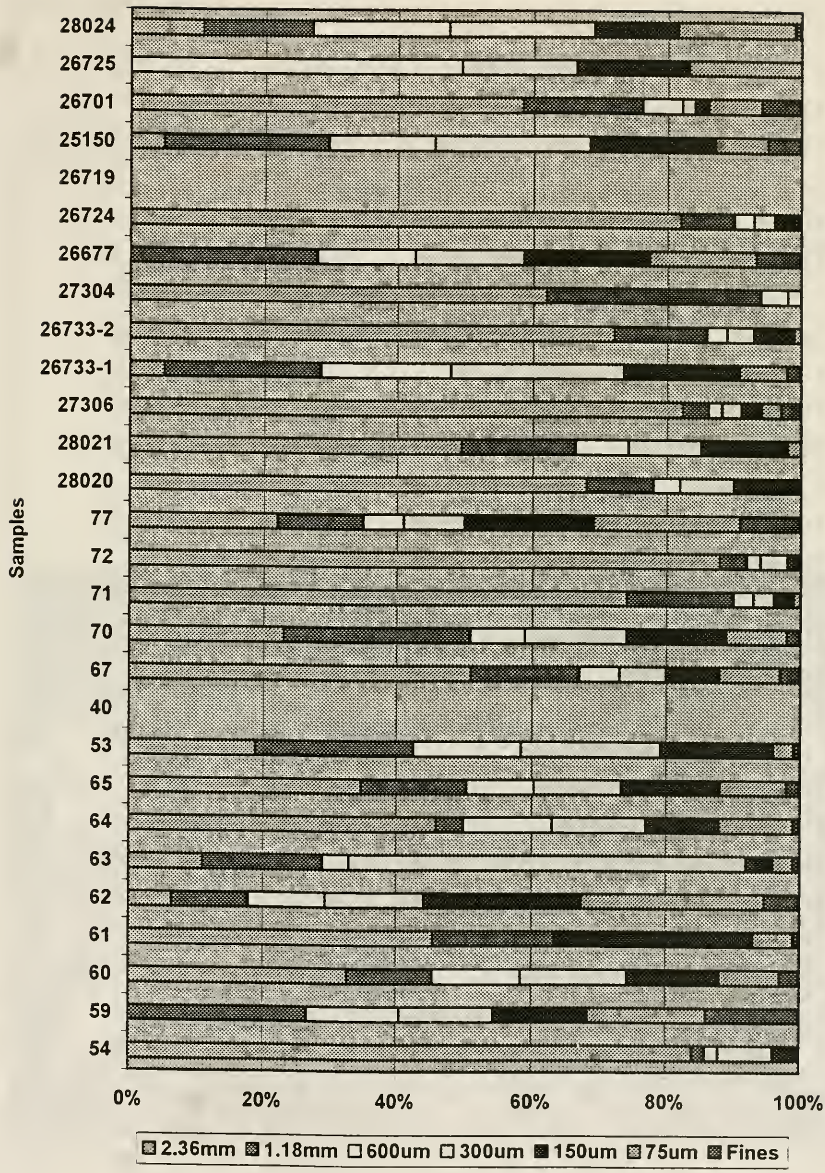
Particle Size Distribution							
Sample	% 2.36 mm	% 1.18 mm	% 600 µm	% 300 µm	% 150 µm	% 75 µm	% Fines
Division 6							
37	92.76	1.24	0.46	0.72	2.28	2.09	0.46
101	55.0	20.0	17.5	7.5	0	0	0
Division 5							
36	81.61	6.95	2.02	6.95	0.22	2.02	0.22
83	9.3	30.23	11.63	13.95	11.63	11.63	11.63
84	0	62.5	25.0	0	0	12.5	0
97	56	44	0	0	0	0	0
98	25.6	22.22	8.7	10.63	14.49	14.49	3.86
99	0	13.04	13.04	15.22	32.6	26.09	0
105	13.33	20.0	13.33	18.33	21.67	13.33	0
107	16.22	10.81	27.02	24.32	18.91	0	0
26	82.25	8.87	1.61	1.61	2.41	2.41	0.81
82	0	21.0	16.0	16.0	32.0	16.0	0
95	0	37.21	23.26	20.93	10.46	4.65	3.49
27	53.44	18.10	7.75	6.89	5.17	5.17	3.44
38	76	3.2	3.2	16.0	1.6	0	0
80	10.29	10.55	2.37	7.91	36.68	27.18	5.01
81	70.17	8.77	7.02	3.5	5.26	5.26	0
88	0	0	13.79	27.59	24.14	24.14	10.34
90	0	35.72	50.0	0	14.28	0	0
Division 4							
28	12.5	0	25.0	12.5	12.5	25.0	12.5
34	20.0	20.0	0	20.0	20.0	20.0	0
35	20.31	9.37	10.93	14.06	20.31	18.75	6.25
58	40.0	20.0	0	20.0	20.0	0	0

Particle Size Distribution							
Sample	% 2.36 mm	% 1.18 mm	% 600 mm	% 300 µm	% 150 µm	% 75 µm	% Fines
Division 2							
54	83.92	1.88	2.09	7.72	3.9	0.42	0
59	0	27.27	13.64	13.64	13.64	18.18	13.63
60	32.58	12.5	12.5	16.07	14.29	9.38	2.68
61	45.91	17.61	0	0	29.56	5.66	1.25
62	6.25	15.62	10.94	14.06	21.87	25.78	5.47
65	34.54	15.91	9.54	13.18	15.0	10.0	1.82
53	18.62	24.02	15.65	21.62	16.65	3.0	0.6
40	0	0	0	0	0	0	0
67	51.37	16.29	6.02	7.27	7.52	8.6	3.0
70	22.99	27.59	8.04	14.94	14.94	9.20	2.30
71	73.58	16.37	3.06	2.84	2.84	1.31	0
72	88.02	3.74	2.49	3.74	1.99	0	0
28020	68.0	10.0	4.0	9.0	10.0	0	0
27306	83.5	3.81	2.28	2.79	2.79	2.54	2.28
26733-1	4.55	22.73	22.08	25.32	16.56	7.14	1.62
26733-2	71.89	13.73	3.27	3.92	5.88	1.31	0
27304	62.11	31.58	4.21	2.1	0	0	0
26677	20.98	22.38	11.19	12.59	14.69	12.59	5.59
26724	81.58	7.68	2.85	2.85	2.63	1.97	0.44
26719	0	0	0	0	0	0	0
25150	4.62	25.13	15.89	22.56	18.97	8.21	4.62
26701	58.82	17.65	5.88	1.96	1.96	7.84	5.88
26725	0	0	50.0	16.67	16.67	16.67	0
28024	10.86	13.48	20.81	22.38	13.09	18.06	1.31

PARTICLE SIZE DISTRIBUTION



PARTICLE SIZE DISTRIBUTION



COARSE FRACTION EXAMINATION	SAMPLE #:26

Floor Name: Bernal

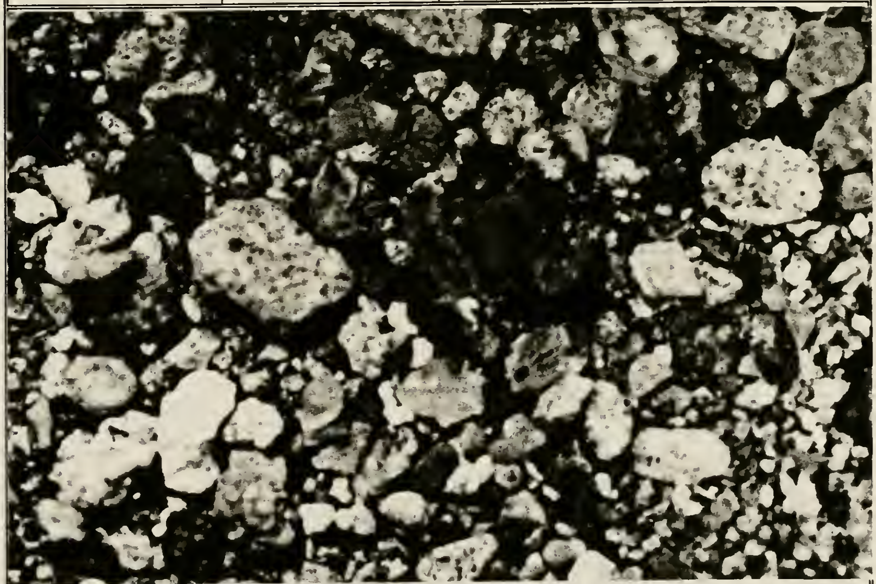
Sample Location: Structure 26, south of Tartan.

Division: 5, MAS 9	**Date:** A.D. 440 - 450	**Magnification:** 10x

Shapes: Round, subround, and subangular.
Colors: Brown, white, gray, tan, orange, white, translucent.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	2.04	82.25
16	**1.18 mm**	0.22	8.87
30	**600 μm**	0.04	1.61
50	**300 μm**	0.04	1.61
100	**150 μm**	0.06	2.41
200	**75 μm**	0.06	2.41
Pan		0.02	0.81



COARSE FRACTION EXAMINATION	SAMPLE #:27

Floor Name: Mot Mot

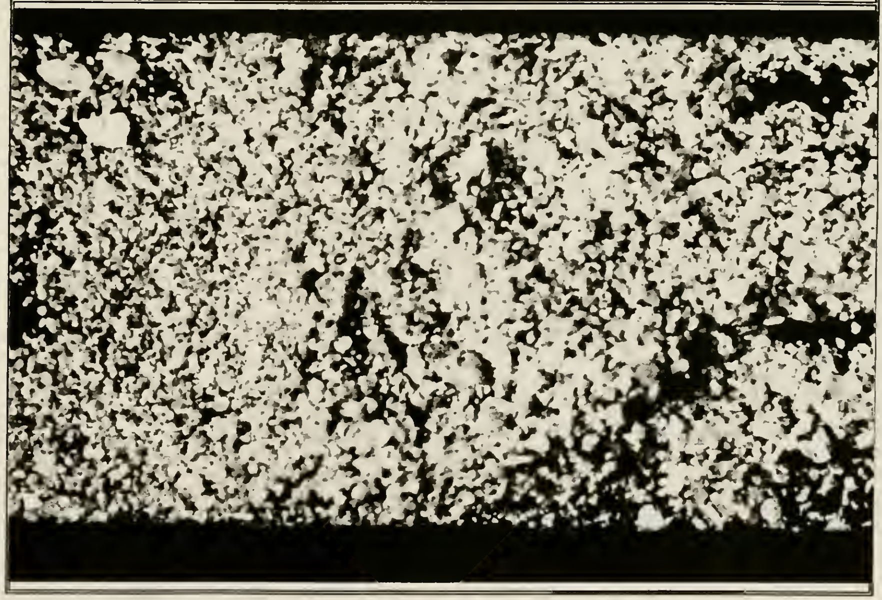
Sample Location: Northeast Court Group, north of Tartan.

Division: 5, MAS 7	**Date:** A.D. 460 - 470	**Magnification:** 8.75 x

Shapes: Round, subround, and subangular.
Colors: Tan, pink, orange, translucent, beige, gray, and rust.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	1.86	53.44
16	1.18 mm	0.63	18.10
30	600 µm	0.27	7.75
50	300 µm	0.24	6.89
100	150 µm	0.18	5.17
200	75 µm	0.18	5.17
Pan		0.12	3.44



COARSE FRACTION EXAMINATION	SAMPLE #:28

Floor Name: Division 4 Court 4C (Sharer)

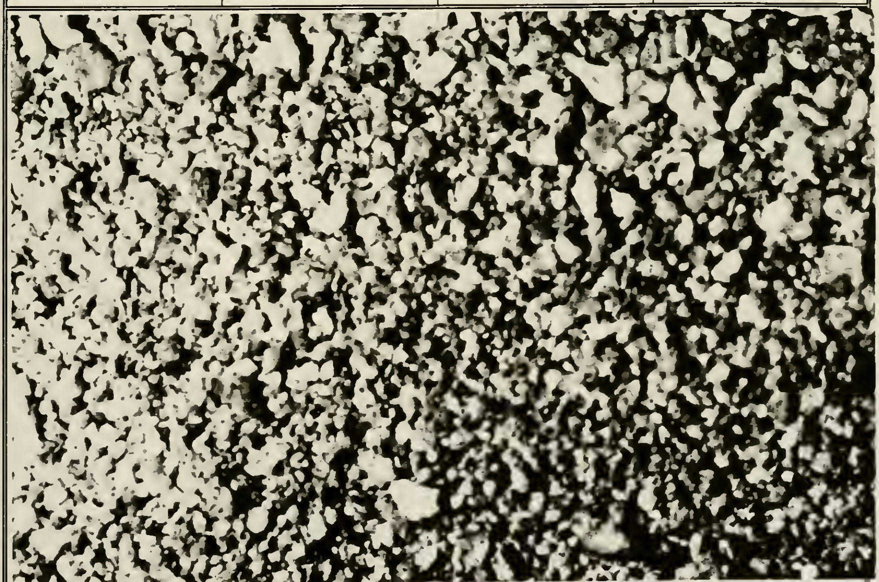
Sample Location: Northeast Court Group, south of Heron.

Division: 4	**Date:** A.D. 480 - 520	**Magnification:** 10 x

Shapes: Subround, and subangular.
Colors: Rust, brown, green, pink, tan, white, and translucent.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.02	12.5
16	**1.18 mm**	0	0
30	**600 µm**	0.04	25
50	**300 µm**	0.02	12.5
100	**150 µm**	0.02	12.5
200	**75 µm**	0.04	25
Pan		0.02	12.5



COARSE FRACTION EXAMINATION	SAMPLE #: 34

Floor Name: Gordon

Sample Location: Northeast Court Group, north of Toucan.

Division: 4	**Date:** A.D. 480 - 520	**Magnification:** 5x

Shapes: Subround, and subangular.
Colors: Reddish-brown, gray, white, pink, green, yellow, rust, and brown.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0.03	20
16	1.18 mm	0.03	20
30	600 μm	0	0
50	300 μm	0.03	20
100	150 μm	0.03	20
200	75 μm	0	0
Pan		0.03	20

COARSE FRACTION EXAMINATION	SAMPLE #:35

Floor Name: Toucan Interior

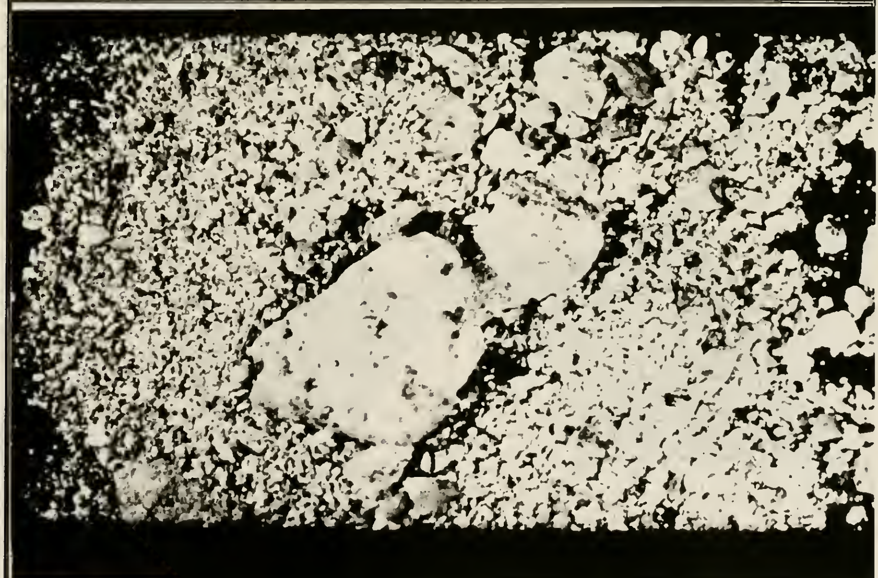
Sample Location: Northeast Court Group, inside north central doorway.

Division: 4	**Date:** A.D. 480 - 520	**Magnification:** 5x

Shapes: Round, subround, and subangular.
Colors: Gray, brown, orange, tan, and green.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.26	20.31
16	**1.18 mm**	0.12	9.37
30	**600 µm**	0.14	10.93
50	**300 µm**	0.18	14.06
100	**150 µm**	0.26	20.31
200	**75 µm**	0.24	18.75
Pan		0.08	6.25



COARSE FRACTION EXAMINATION	SAMPLE #:36

Floor Name: Papo

Sample Location: Northeast Court Group, below Loro.

Division: 5, MAS 11	**Date:** A.D. 420 – 430	**Magnification:** 11.25x

Shapes: Round, subround, and subangular.
Colors: Gray, tan, white-brown, green, and dark red.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	14.56	81.61
16	**1.18 mm**	1.24	6.95
30	**600 μm**	0.36	2.02
50	**300 μm**	1.24	6.95
100	**150 μm**	0.04	0.22
200	**75 μm**	0.36	2.02
Pan		0.04	0.22

COARSE FRACTION EXAMINATION	**SAMPLE #:37**

Floor Name: Chinchilla

Sample Location: Northeast Court Group, below Loro.

Division: 6	**Date:** A.D. 250 - 420	**Magnification:** 5x

Shapes: Round, subround, and subangular.
Colors: Gray, green, tan, translucent, brown, orange, black, and white.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	14.23	92.76
16	**1.18 mm**	0.19	1.24
30	**600 μm**	0.07	0.46
50	**300 μm**	0.11	0.72
100	**150 μm**	0.35	2.28
200	**75 μm**	0.32	2.09
Pan		0.07	0.46

COARSE FRACTION EXAMINATION	SAMPLE #:38

Floor Name: Loro Interior

Sample Location: Northeast Court Group, 2 meters inside central doorway.

Division: 5, MAS 11	**Date:** A.D. 460 - 470	**Magnification:** 5x

Shapes: Round, subround, and subangular.
Colors: Gray, tan, brown, and orange.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	1.09	76
16	**1.18 mm**	0.08	3.2
30	**600 µm**	0.08	3.2
50	**300 µm**	0.4	16
100	**150 µm**	0.04	1.6
200	**75 µm**	0	0
Pan		0	0

COARSE FRACTION EXAMINATION	SAMPLE #: 53

Floor Name: Division 2 Court

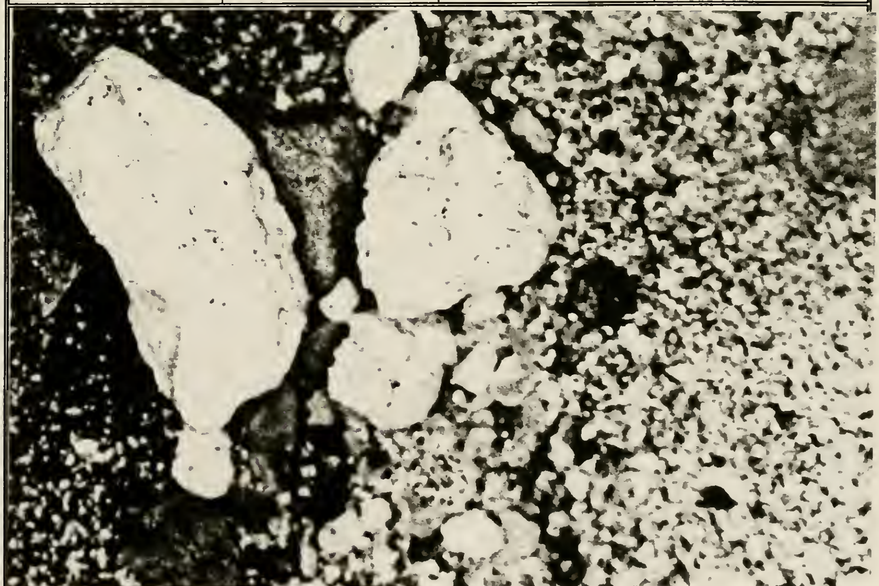
Sample Location: Northeast Court Group, court floor south of Chachalaca

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

Shapes: Round, subround, and subangular.
Colors: White, green, rust, brown, black, pink, gray, and orange.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	1.86	18.62
16	**1.18 mm**	2.4	24.02
30	**600 µm**	1.56	15.65
50	**300 µm**	2.16	21.62
100	**150 µm**	1.65	16.65
200	**75 µm**	0.3	3.0
Pan		0.6	0.6

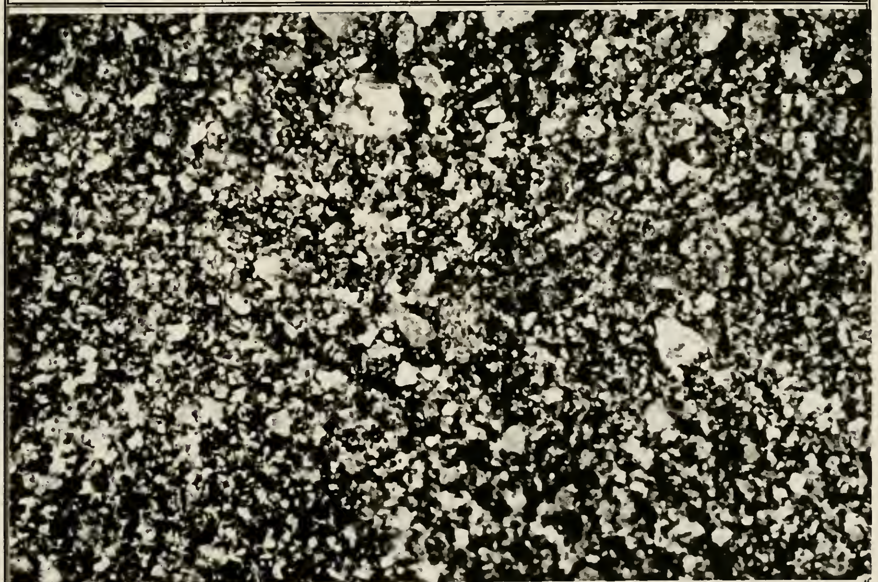


COARSE FRACTION EXAMINATION	SAMPLE #: 54	
Floor Name: Chachalaca Interior		
Sample Location: Northeast Court Group, south of ripped out bench		
Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x

Shapes: Round, subround, and subangular.
Colors: Gray, green, tan, orange, and pink.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	12.06	83.92
16	**1.18 mm**	.27	1.88
30	**600 μm**	0.3	2.09
50	**300 μm**	1.11	7.72
100	**150 μm**	0.57	3.9
200	**75 μm**	0.06	0.42
Pan		0	0

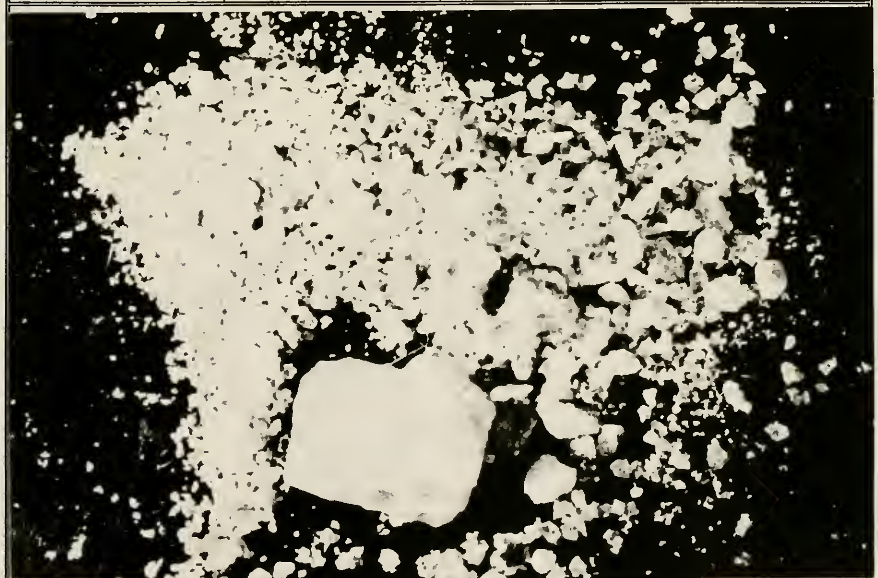


COARSE FRACTION EXAMINATION		SAMPLE #: 58
Floor Name: Sharer		
Sample Location: Northeast Court Group, south of Toucan		
Division: 4	**Date:** A.D. 480 - 520	**Magnification:** 6.25x

Shapes: Subround, and subangular.
Colors: White, pink, yellow, green, brown, and black.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.04	40
16	**1.18 mm**	0.02	20
30	**600 μm**	0	0
50	**300 μm**	0.02	20
100	**150 μm**	0.02	20
200	**75 μm**	0	0
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 59

Floor Name: Chachalaca Floor #1

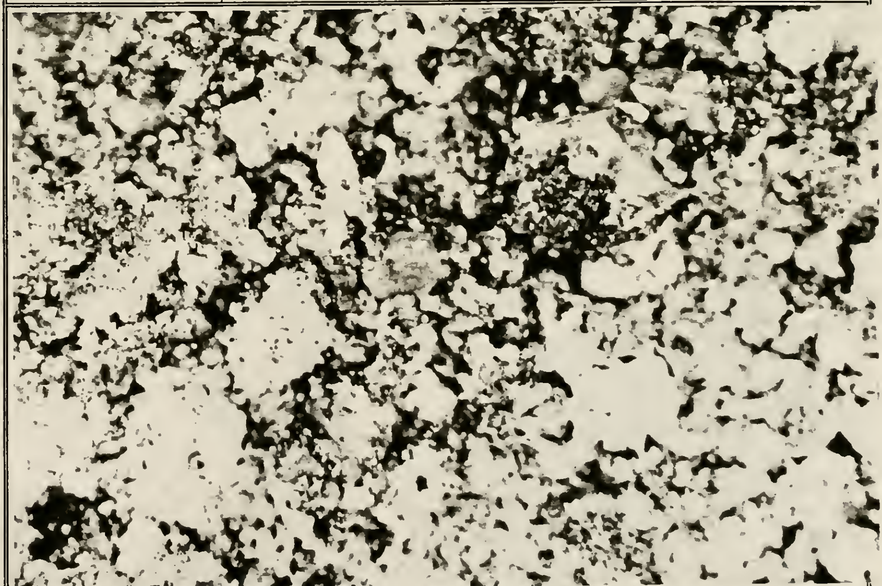
Sample Location: Northeast Court Group, abuts east side. Last plaza floor surface.

Division: 2	Date: A.D. 540 - 650	Magnification: 7.5x

Shapes: Round, subround, and subangular.
Colors: Gray, green, tan, orange, and pink.

SIEVE ANALYSIS

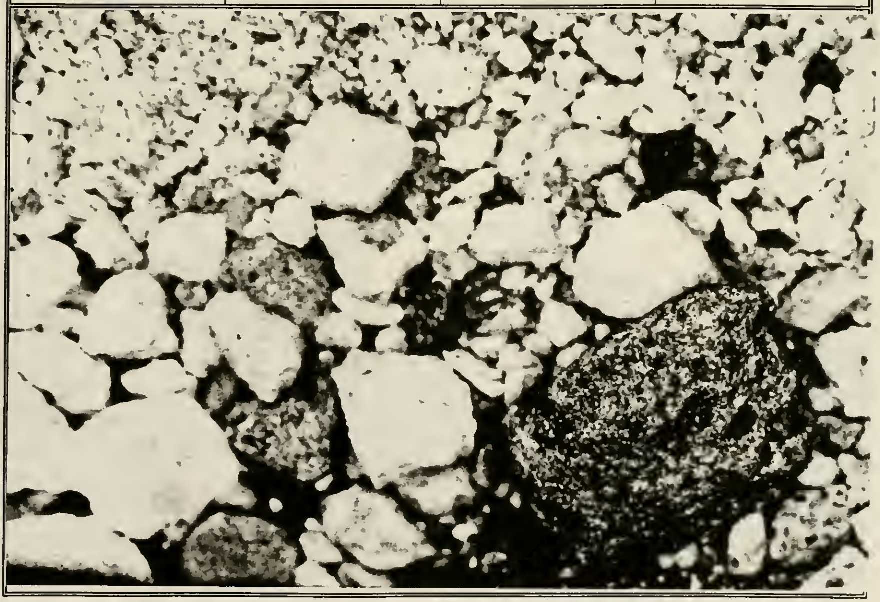
Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0	0
16	**1.18 mm**	0.24	27.27
30	**600 μm**	0.12	13.64
50	**300 μm**	0.12	13.64
100	**150 μm**	0.12	13.64
200	**75 μm**	0.16	18.18
Pan		0.12	13.63



COARSE FRACTION EXAMINATION			SAMPLE #: 60
Floor Name: Chachalaca Floor #2			
Sample Location: Northeast Court Group, plaza floor east side.			
Division: 2	**Date:** A.D. 540 - 650		**Magnification:** 4x
Shapes: Subround, and subangular. **Colors:** Gray, green, brown, tan, white, rust, and yellow.			

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	2.19	32.58
16	**1.18 mm**	0.84	12.5
30	**600 μm**	0.84	12.5
50	**300 μm**	1.08	16.07
100	**150 μm**	0.96	14.29
200	**75 μm**	0.63	9.38
Pan		0.18	2.68



COARSE FRACTION EXAMINATION	SAMPLE #: 61

Floor Name: Chachalaca Floor #3

Sample Location: Northeast Court Group, 3rd plaza surface above top of Indigo.

Division: 2	Date: A.D. 540 - 650	Magnification: 3.75x

Shapes: Subround, and subangular.
Colors: Green, yellow, and black.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	2.19	45.91
16	1.18 mm	0.84	17.61
30	600 µm	0	0
50	300 µm	0	0
100	150 µm	1.42	29.56
200	75 µm	0.27	5.66
Pan		0.06	1.25

COARSE FRACTION EXAMINATION	SAMPLE #: 62

Floor Name: Chachalaca Floor #4

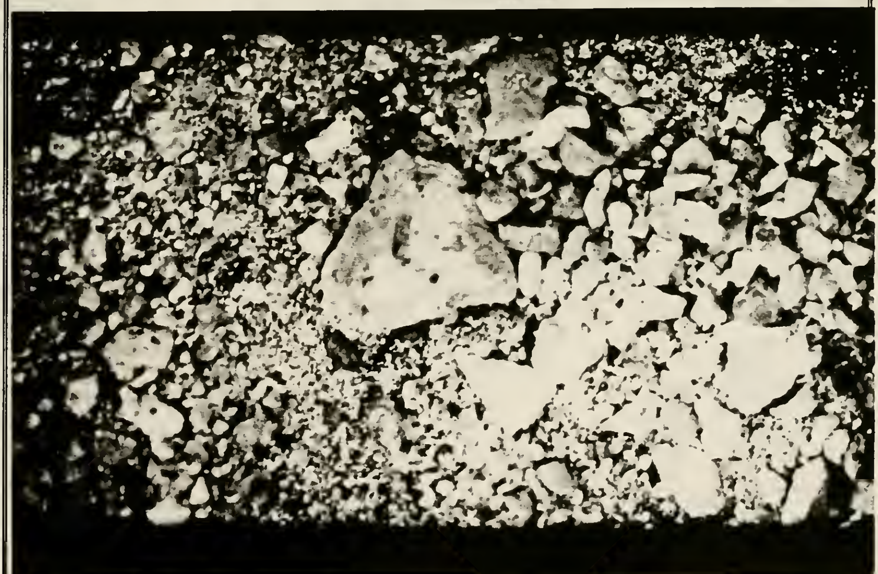
Sample Location: Northeast Court Group, 2nd plaza surface above top of Indigo.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

Shapes: Subround, and subangular.
Colors: Green, yellow, tan, rust, brown, gray, and pink.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.16	6.25
16	**1.18 mm**	0.4	15.62
30	**600 μm**	0.28	10.94
50	**300 μm**	0.36	14.06
100	**150 μm**	0.56	21.87
200	**75 μm**	0.66	25.78
Pan		0.14	5.47



COARSE FRACTION EXAMINATION	SAMPLE #: 65

Floor Name: Chachalaca Floor #7

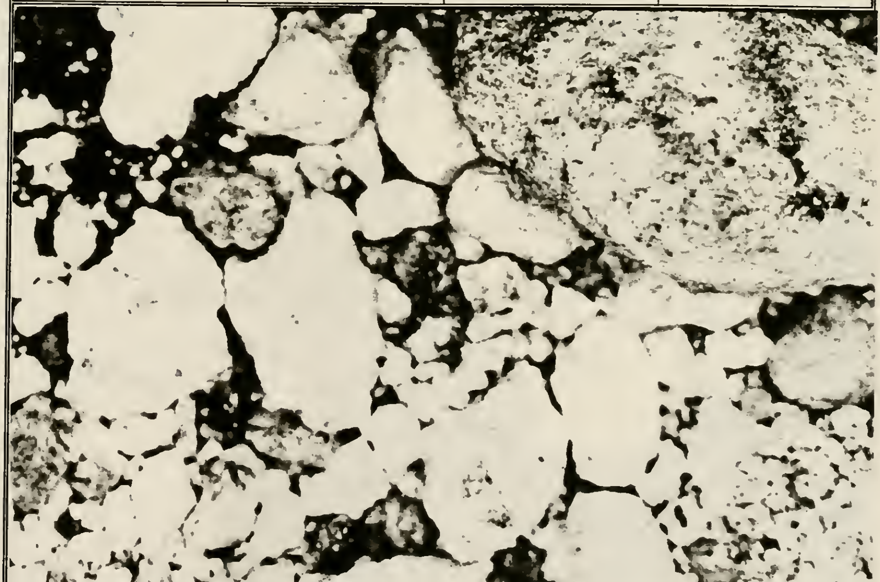
Sample Location: Northeast Court Group, abuts east side above last Div. 2 surface

Division: 2	Date: A.D. 540 - 650	Magnification: 5x

Shapes: Round, subround, and subangular.
Colors: Green, red, pink, and rust.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0.76	34.54
16	1.18 mm	0.35	15.91
30	600 μm	0.21	9.54
50	300 μm	0.29	13.18
100	150 μm	0.33	15.00
200	75 μm	0.22	10.00
Pan		0.04	1.82



COARSE FRACTION EXAMINATION	SAMPLE #: 67

Floor Name: Indigo

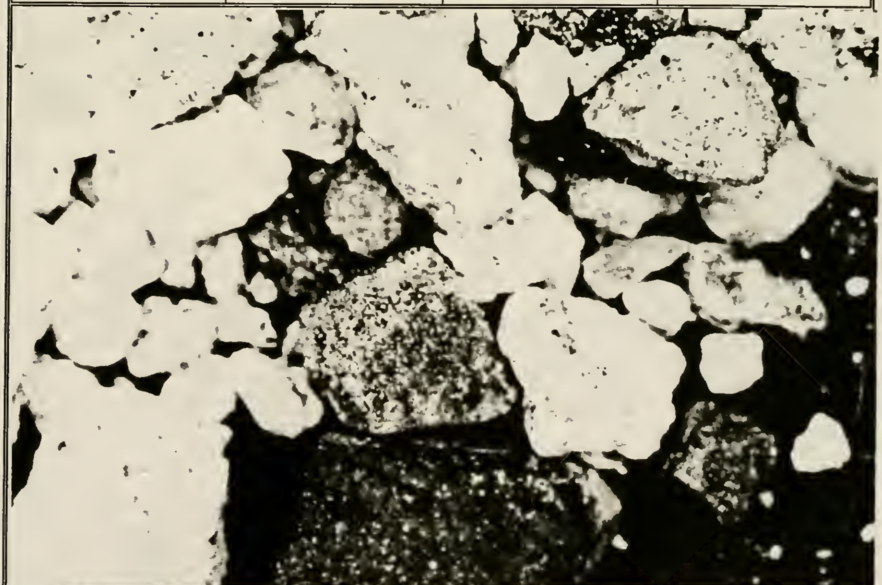
Sample Location: Northeast Court Group. Floor upon which Indigo rests.

Division: 2	Date: A.D. 540 - 650	Magnification: 7.5x

Shapes: Subround, and subangular.
Colors: Gray, brown, green, tan, red, gray, and white.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	4.10	51.37
16	**1.18 mm**	1.30	16.29
30	**600 µm**	0.48	6.02
50	**300 µm**	0.58	7.27
100	**150 µm**	0.60	7.52
200	**75 µm**	0.68	8.60
Pan		0.24	3.00



COARSE FRACTION EXAMINATION	SAMPLE #: 70

Floor Name: 22 Chiquito

Sample Location: Northeast Court Group. Floor atop highest terrace

Division: 2	Date: A.D. 540 - 650	Magnification: 5x

Shapes: Subround and subangular.
Colors: Brown, gray, green, rust on white, tan, and reddish-brown.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.4	22.99
16	**1.18 mm**	0.48	27.59
30	**600 μm**	0.14	8.04
50	**300 μm**	0.26	14.94
100	**150 μm**	0.26	14.94
200	**75 μm**	0.16	9.20
Pan		0.04	2.30

COARSE FRACTION EXAMINATION	SAMPLE #: 71

Floor Name: 22 Chiquito

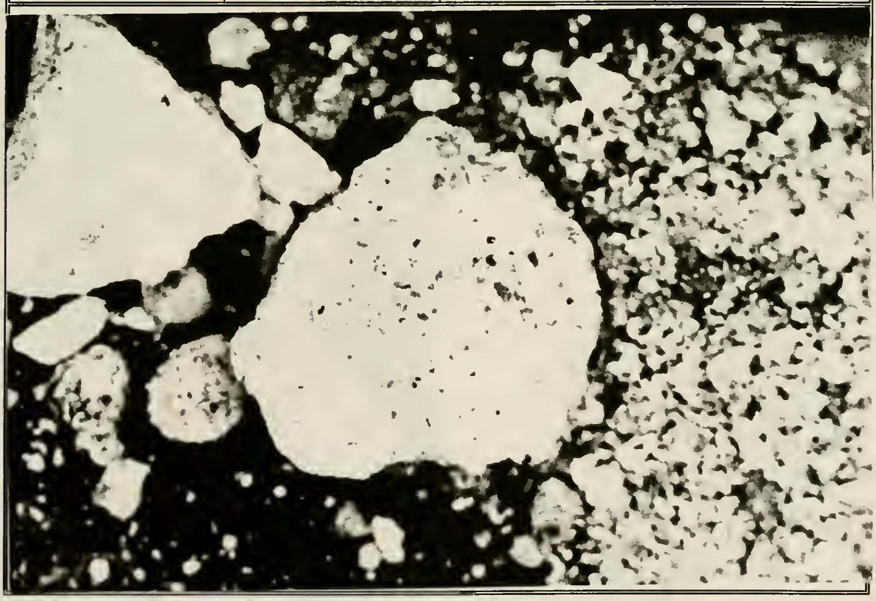
Sample Location: Northeast Court Group. 1st Floor (lowest) burying 22 Chiquito.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x

Shapes: Subround and subangular.
Colors: Green, gray, white with rust, brown, and orange.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	7.74	73.58
16	**1.18 mm**	1.50	16.37
30	**600 μm**	0.28	3.06
50	**300 μm**	0.26	2.84
100	**150 μm**	0.26	2.84
200	**75 μm**	0.12	1.31
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 72

Floor Name: 22 Chiquito

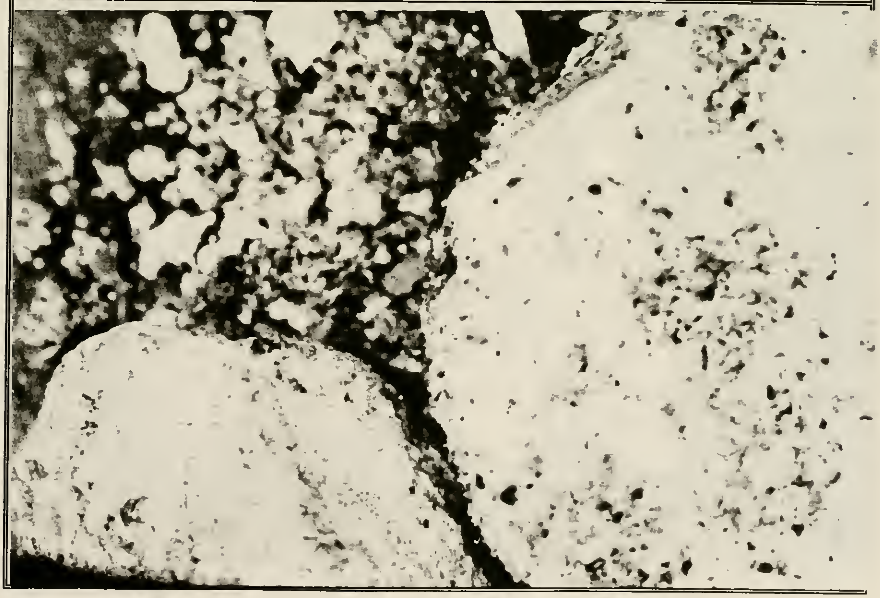
Sample Location: Northeast Court Group, 2nd Floor (lowest) burying 22 Chiquito.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x

Shapes: Subround and subangular.
Colors: White with rust, green, tan, gray, orange, and brown.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	7.06	88.02
16	**1.18 mm**	0.3	3.74
30	**600 µm**	0.2	2.49
50	**300 µm**	0.3	3.74
100	**150 µm**	0.16	1.99
200	**75 µm**	0	0
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 80	
Floor Name: Division 5 Bernal		
Sample Location: MAS, at juncture with Chaj.		
Division: 5, MAS 7	**Date:** A.D. 460 - 470	**Magnification:** 7.5x

Shapes: Subround and subangular.
Colors: White, brown, gray, tan, and pink.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.78	10.29
16	**1.18 mm**	0.8	10.55
30	**600 μm**	0.18	2.37
50	**300 μm**	0.6	7.91
100	**150 μm**	2.78	36.68
200	**75 μm**	2.06	27.18
Pan		0.38	5.01

COARSE FRACTION EXAMINATION	SAMPLE #: 81

Floor Name: Chaj

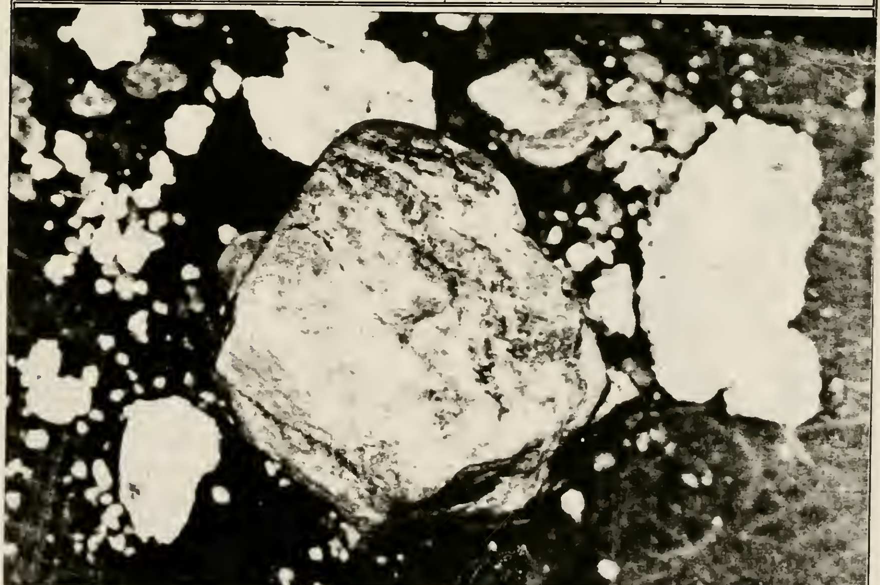
Sample Location: MAS, abuts Ceiba on north side, under Acatan

Division: 5, MAS 7	**Date:** A.D. 460 - 470	**Magnification:** 7.5x

Shapes: Round, subround and subangular.
Colors: Gray, brown, green, tan with rust, white, and red.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.8	70.17
16	**1.18 mm**	0.1	8.77
30	**600 μm**	0.08	7.02
50	**300 μm**	0.04	3.5
100	**150 μm**	0.06	5.26
200	**75 μm**	0.06	5.26
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 82

Floor Name: Xox

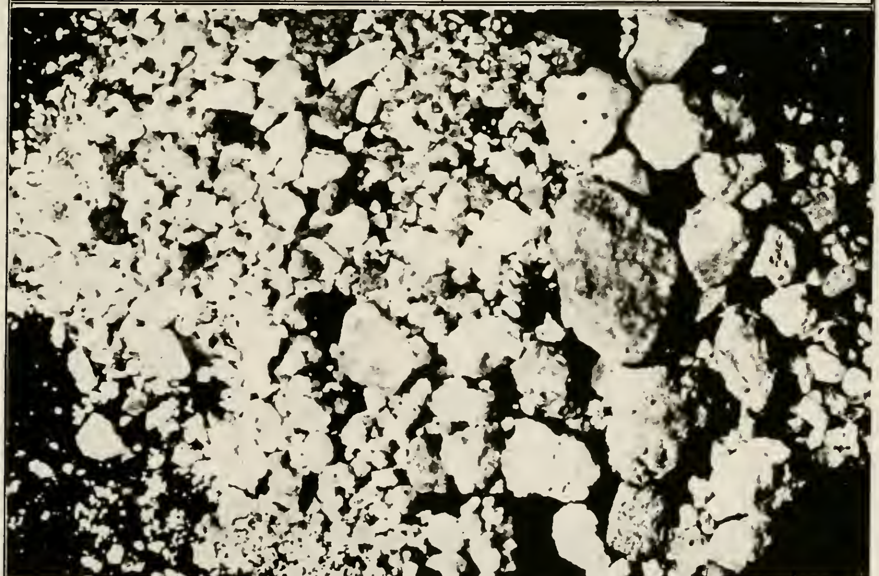
Sample Location: MAS, runs under Acatan, abuts north side of Cedro.

Division: 5, MAS 9	Date: A.D. 440 - 450	Magnification: 7.5x

Shapes: Subround and subangular.
Colors: Gray, brown, green, and tan.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0	0
16	**1.18 mm**	0.08	21
30	**600 μm**	0.06	16
50	**300 μm**	0.06	16
100	**150 μm**	0.12	32
200	**75 μm**	0.06	16
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 83

Floor Name: Pec

Sample Location: MAS, runs under Caoba.

Division: 5, MAS 11	Date: A.D. 420 - 430	Magnification: 6.25x

Shapes: Subround and subangular.
Colors: Gray, brown, green, orange, pink, white, and translucent.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0.08	9.3
16	1.18 mm	0.26	30.23
30	600 µm	0.1	11.63
50	300 µm	0.12	13.95
100	150 µm	0.1	11.63
200	75 µm	0.1	11.63
Pan		0.1	11.63

COARSE FRACTION EXAMINATION	SAMPLE #: 84

Floor Name: Lu

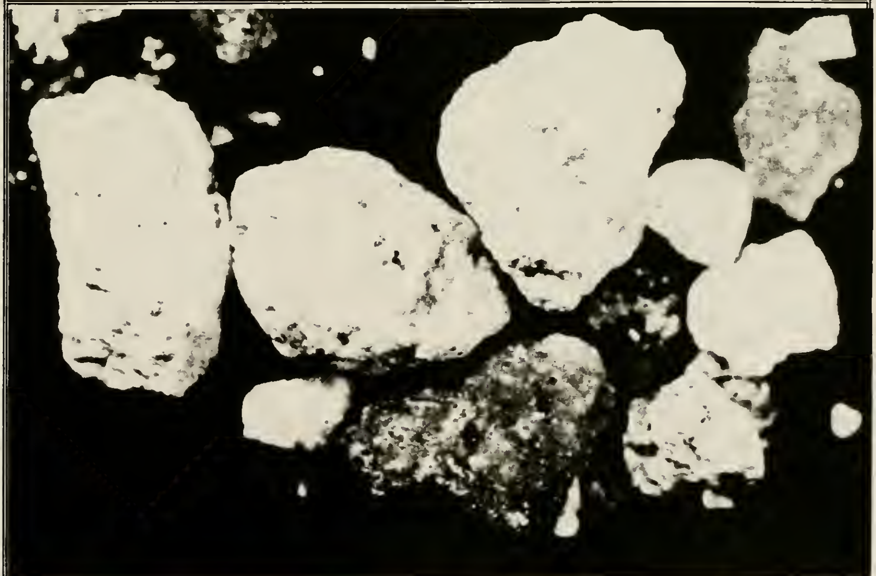
Sample Location: MAS, runs under Margarita, north side.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 11.25x

Shapes: Subround and subangular.
Colors: Green, tan with rust, translucent pink, and orange.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0	0
16	**1.18 mm**	0.1	62.5
30	**600 µm**	0.04	25
50	**300 µm**	0	0
100	**150 µm**	0	0
200	**75 µm**	0.02	12.5
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 88

Floor Name: Bringuez

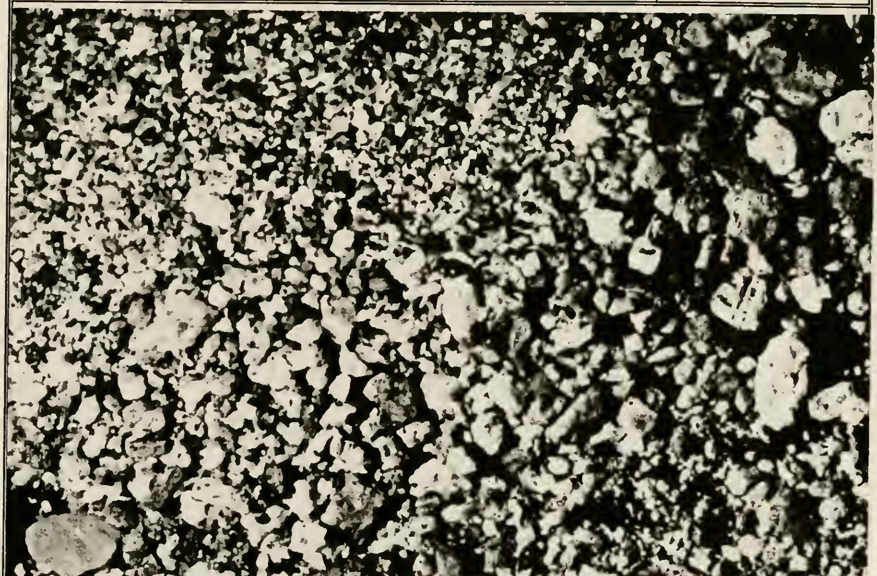
Sample Location: MAS, west of Tuna. Central area of west side.

Division: 5, MAS 7	Date: A.D. 460 - 470	Magnification: 7.5x

Shapes: Round, subround, angular, and subangular.
Colors: Brown, gray, tan, green, white, and reddish-brown.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0	0
16	**1.18 mm**	0	0
30	**600 µm**	0.08	13.79
50	**300 µm**	0.16	27.59
100	**150 µm**	0.14	24.14
200	**75 µm**	0.14	24.14
Pan		0.06	10.34



COARSE FRACTION EXAMINATION	SAMPLE #: 89

Floor Name: Reina

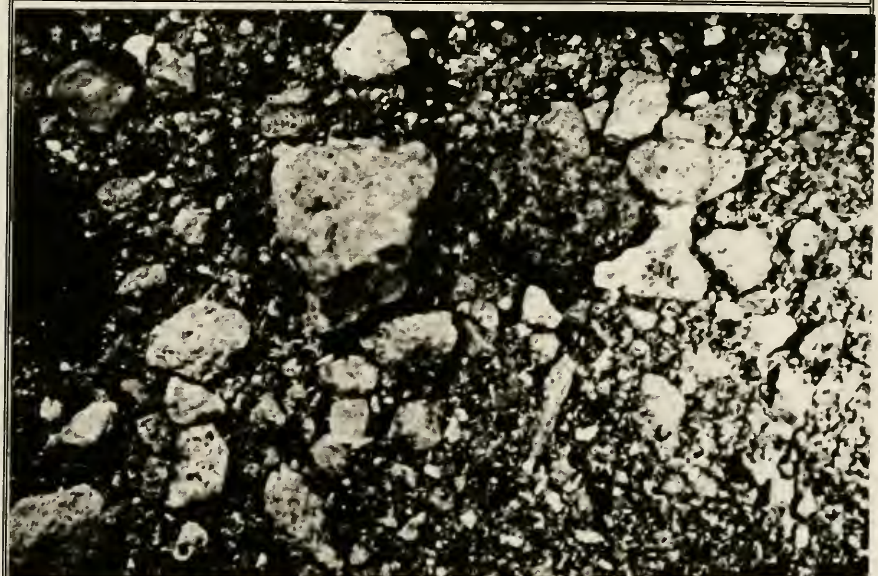
Sample Location: MAS, west of central area of Tuna, west side.

Division: 5, MAS 7	Date: A.D. 460 - 470	Magnification: 5x

Shapes: Subangular and subround.
Colors: Green, gray-brown, tan, rust, gray and translucent white.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0.36	26.86
16	1.18 mm	0.44	32.83
30	600 µm	0.12	8.95
50	300 µm	0.2	14.92
100	150 µm	0.18	13.43
200	75 µm	0	0
Pan		0.4	2.98



COARSE FRACTION EXAMINATION	SAMPLE #: 90

Floor Name: Banano

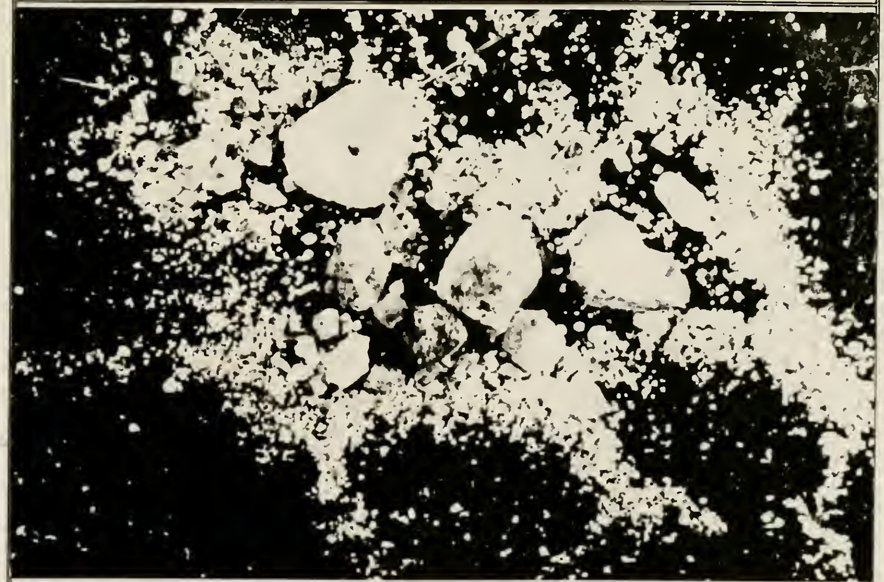
Sample Location: MAS, west of central area of Tuna, below Reina.

Division: 5, MAS 7	Date: A.D. 460 - 470	Magnification: 6.25x

Shapes: Subround and subangular.
Colors: Tan, white, brown, green, gray, and rust.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0	0
16	**1.18 mm**	0.1	35.72
30	**600 µm**	0.14	50
50	**300 µm**	0	0
100	**150 µm**	0.04	14.28
200	**75 µm**	0	0
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 95

Floor Name: Asmen

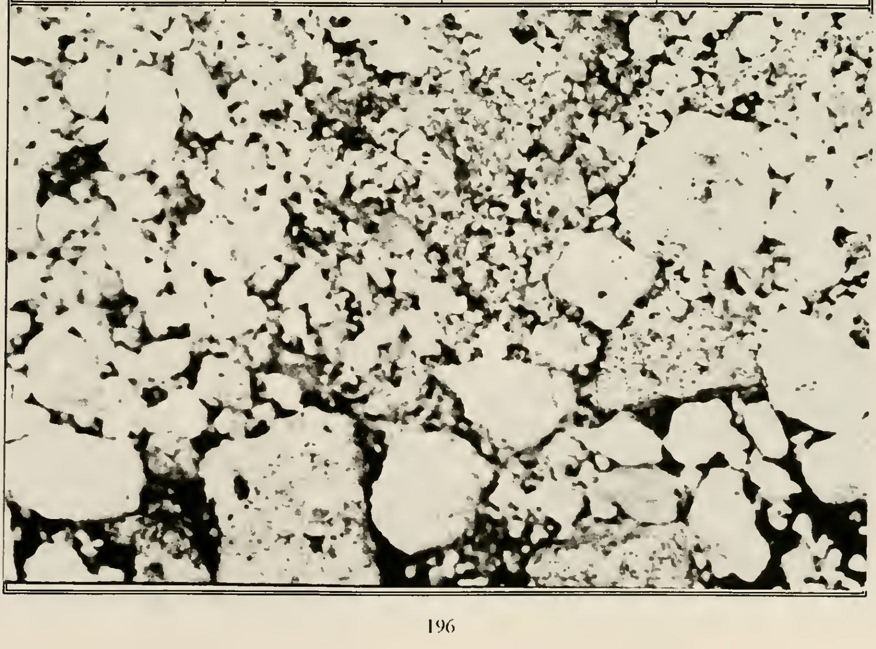
Sample Location: MAS, west of Margarita, below Asmen.

Division: 5, MAS 9	**Date:** A.D. 440 – 450	**Magnification:** 6.25x

Shapes: Subround and subangular.
Colors: Green, yellow, gray, white, rust, and translucent.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0	0
16	1.18 mm	3.2	34.91
30	600 μm	2.0	23.21
50	300 μm	1.8	20.91
100	150 μm	0.9	10.46
200	75 μm	0.4	4.65
Pan		0.12	3.49



COARSE FRACTION EXAMINATION	SAMPLE #: 98

Floor Name: Cruz

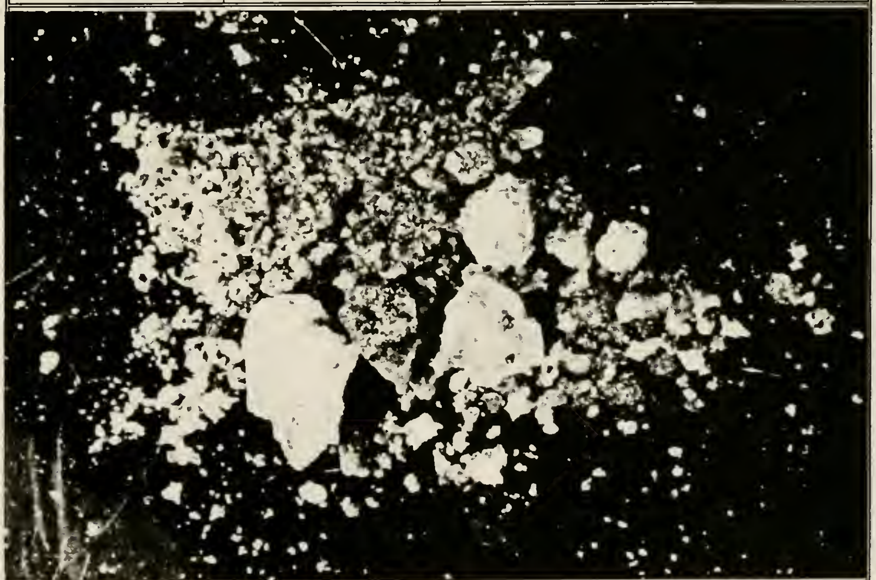
Sample Location: MAS, tops step up of Margarita Platform, west side.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 5x

Shapes: Subround and subangular.
Colors: Green, rust, brown, tan and gray.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.53	25.6
16	**1.18 mm**	0.46	22.22
30	**600 µm**	0.18	8.70
50	**300 µm**	0.22	10.63
100	**150 µm**	0.3	14.49
200	**75 µm**	0.3	14.49
Pan		0.08	3.86



COARSE FRACTION EXAMINATION	SAMPLE #: 99

Floor Name: Burkett

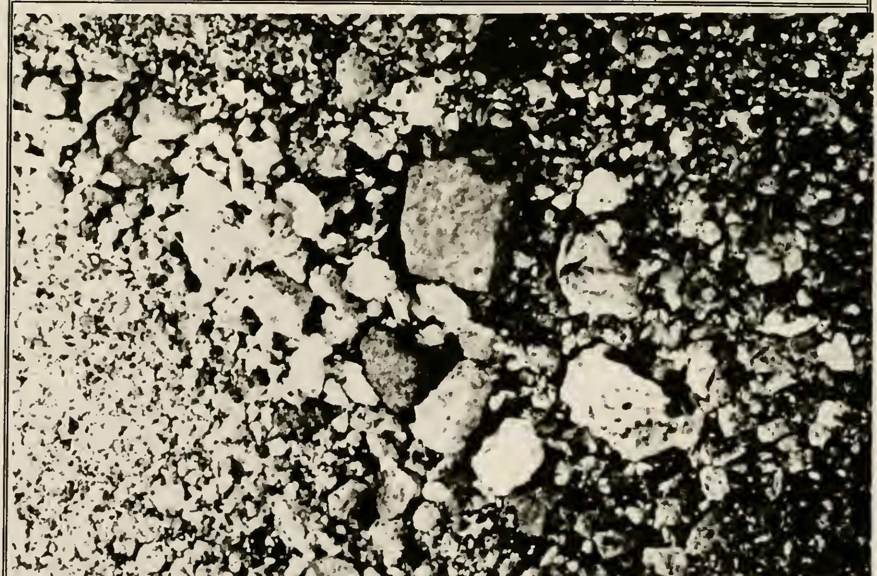
Sample Location: MAS, interior floor of Margarita, Xuk Pi, west side.

Division: 5, MAS 10	Date: A.D. 430 - 440	Magnification: 5x

Shapes: Subround and subangular.
Colors: Tan, rust, brown, gray, black, and green.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0	0
16	1.18 mm	0.12	13.04
30	600 µm	0.12	13.04
50	300 µm	0.14	15.22
100	150 µm	0.3	32.6
200	75 µm	0.24	26.09
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 101

Floor Name: Hun Nal

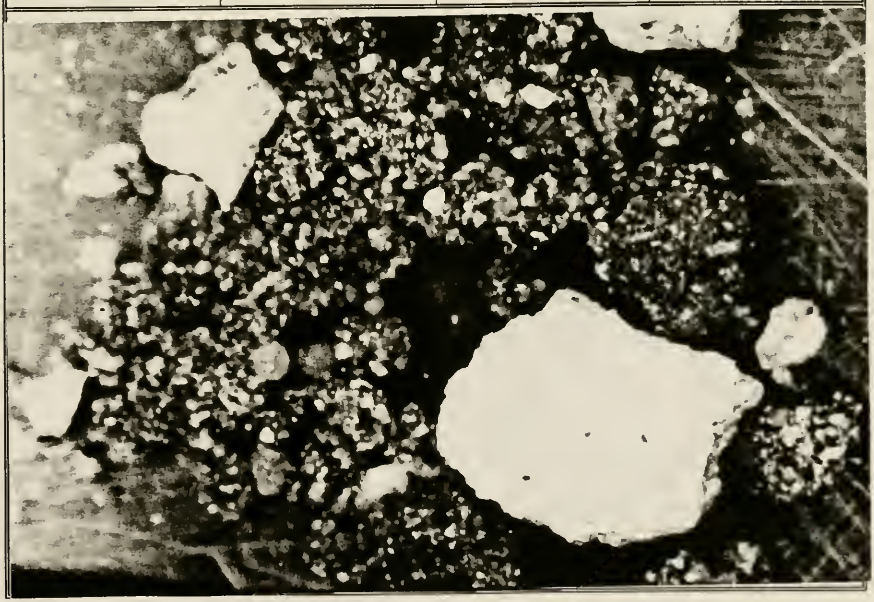
Sample Location: MAS, top of platform, west side.

Division: 6	**Date:** A.D. 250 - 420	**Magnification:** 10x

Shapes: Subround and subangular.
Colors: Green, brown, rust, yellow, white, and tan.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.44	55
16	**1.18 mm**	0.16	20
30	**600 μm**	0.14	17.5
50	**300 μm**	0.06	7.5
100	**150 μm**	0	0
200	**75 μm**	0	0
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 105

Floor Name: Barientos

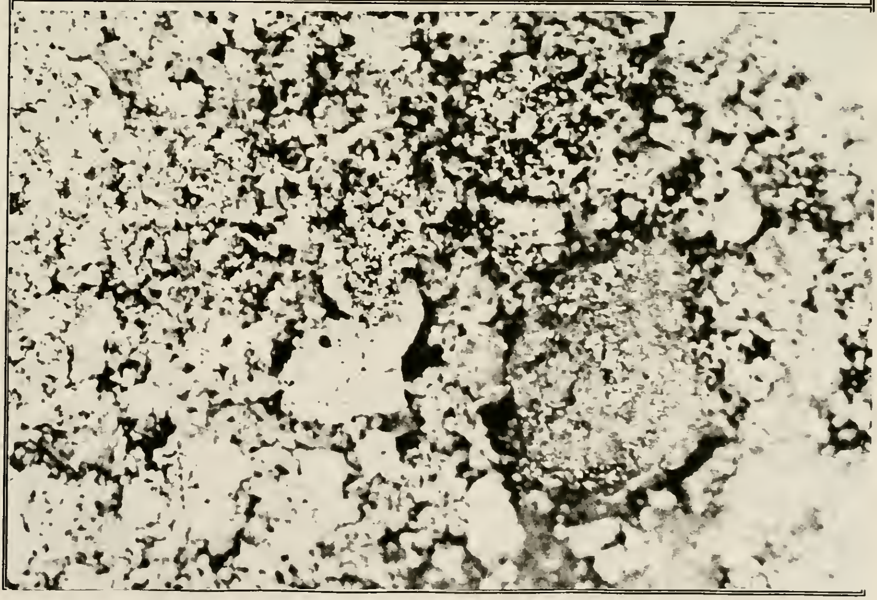
Sample Location: MAS, abuts west side of Papa steps.

Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 10x

Shapes: Subround and subangular.
Colors: Green, brown, rust, tan, and gray.

SIEVE ANALYSIS

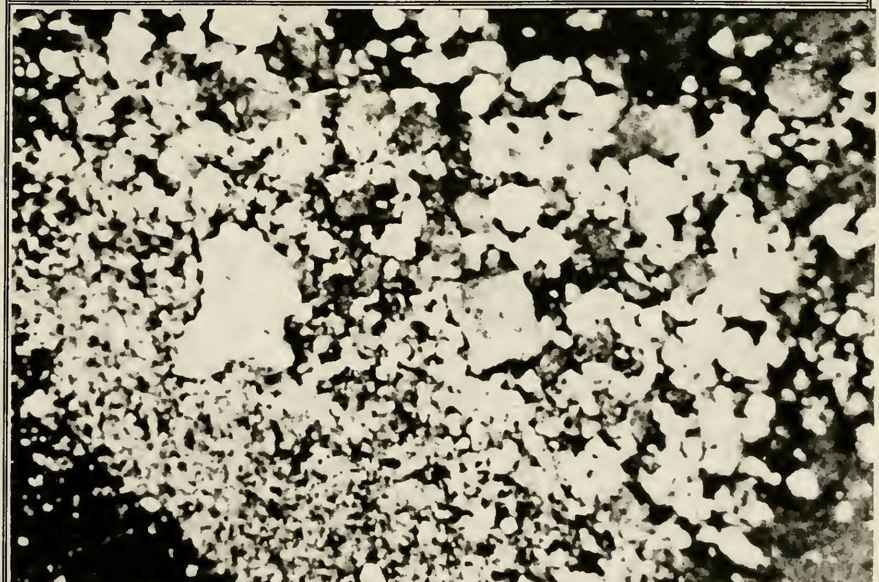
Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0.16	13.33
16	1.18 mm	0.24	20
30	600 µm	0.16	13.33
50	300 µm	0.22	18.33
100	150 µm	0.26	21.67
200	75 µm	0.16	13.33
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 107	
Floor Name: Ramirez		
Sample Location: MAS, integral with base of Papa (built at the same time).		
Division: 5, MAS 10	**Date:** A.D. 430 - 440	**Magnification:** 7.5x
Shapes: Subround and subangular. **Colors:** Green, brown, rust, tan, gray, orange and translucent.		

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.12	16.22
16	**1.18 mm**	0.08	10.81
30	**600 μm**	0.20	27.02
50	**300 μm**	0.18	24.32
100	**150 μm**	0.14	18.91
200	**75 μm**	0	0
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 25150

Floor Name: Piso Don Jorge

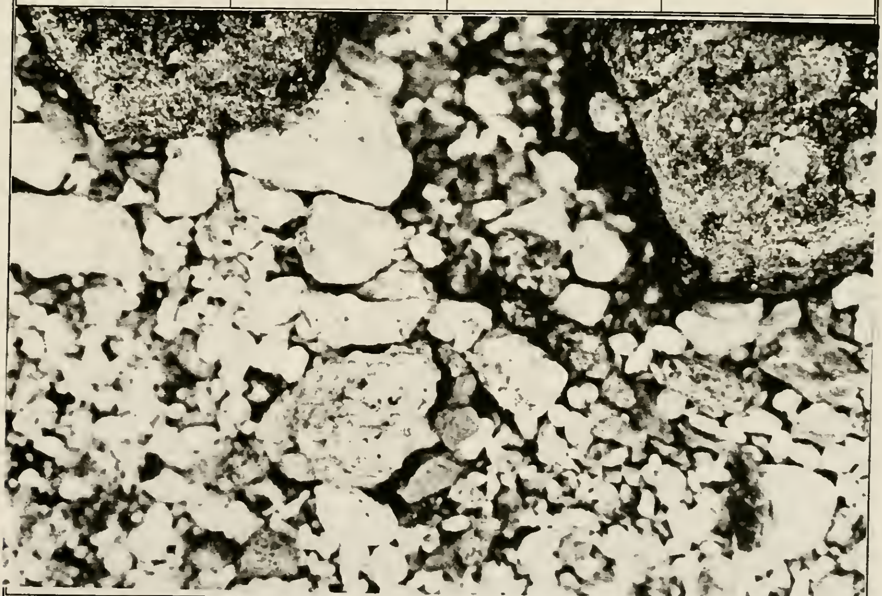
Sample Location: Rosalila, cancels Azul on west side

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x

Shapes: Subangular and subround.
Colors: Brown, green, ivory, gray, rust, and white.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0.18	4.62
16	1.18 mm	0.98	25.13
30	600 µm	0.62	15.89
50	300 µm	0.88	22.56
100	150 µm	0.74	18.97
200	75 µm	0.32	8.21
Pan		0.18	4.62



COARSE FRACTION EXAMINATION	SAMPLE #: 26677

Floor Name: Piso Don Renecito

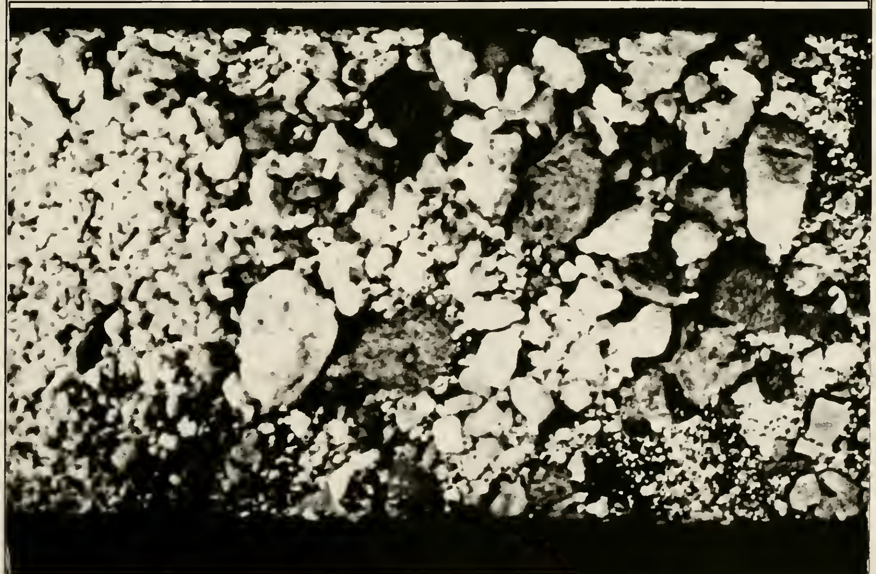
Sample Location: Rosalila, Tunnel 33, west side of Rosalila

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

Shapes: Subangular and subround.
Colors: Brown, tan, green, rust, olive, red-brown, gray, and translucent white.

SIEVE ANALYSIS

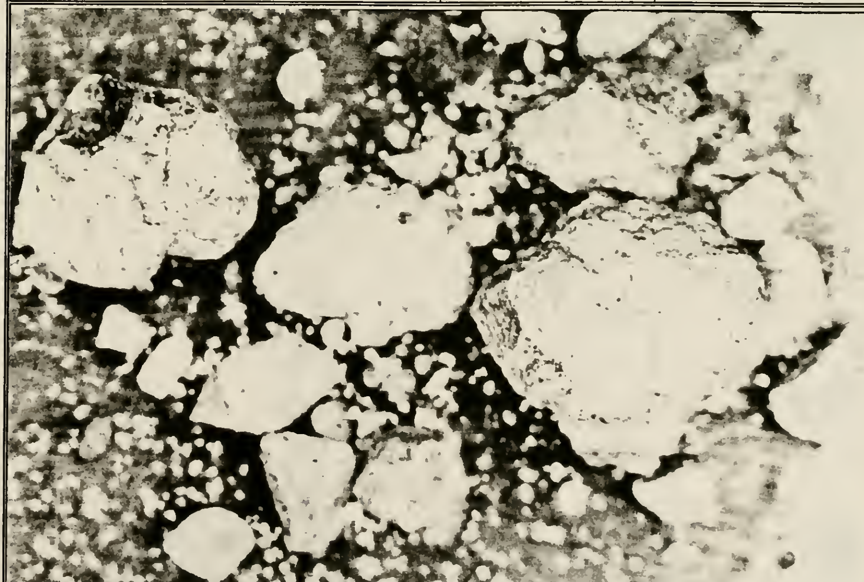
Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0.6	20.98
16	1.18 mm	0.64	22.38
30	600 μm	0.32	11.19
50	300 μm	0.36	12.59
100	150 μm	0.42	14.69
200	75 μm	0.36	12.59
Pan		0.16	5.59



COARSE FRACTION EXAMINATION	SAMPLE #: 26701	
Floor Name: Piso Don Marcos		
Sample Location: Rosalila, interior floor.		
Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x
Shapes: Subangular. **Colors:** Red-gray, green, tan, gray, and brown.		

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.6	58.82
16	**1.18 mm**	0.18	17.65
30	**600 μm**	0.06	5.88
50	**300 μm**	0.02	1.96
100	**150 μm**	0.02	1.96
200	**75 μm**	0.08	7.84
Pan		0.06	5.88



COARSE FRACTION EXAMINATION	SAMPLE #: 26724

Floor Name: Piso Don Gustavo

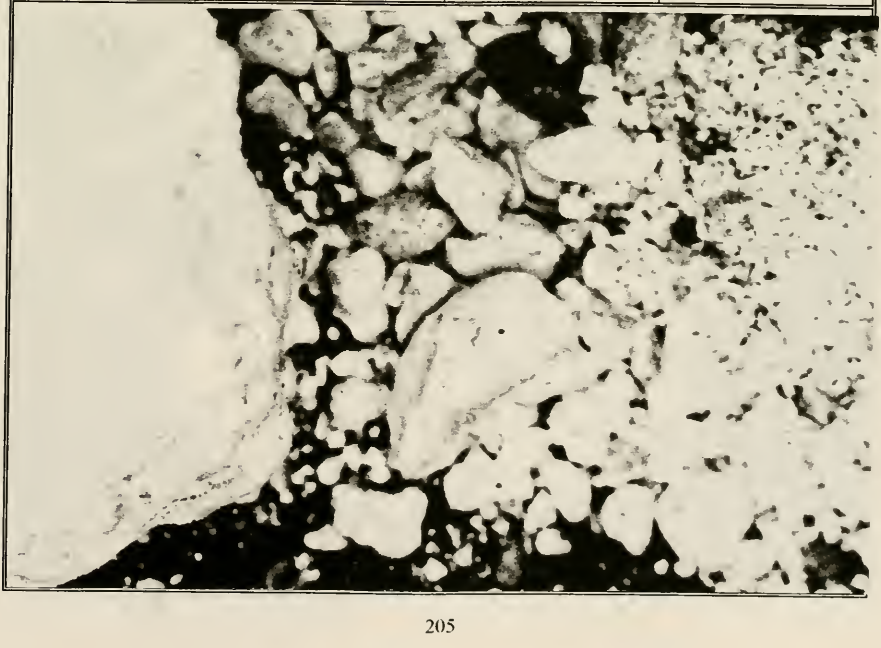
Sample Location: Rosalila, runs between Oropendola and Rosalila. Cancels Azul.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 10x

Shapes: Subround and subangular.
Colors: Rust, green, gray, brown, and tan.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	7.44	81.58
16	**1.18 mm**	0.7	7.68
30	**600 μm**	0.26	2.85
50	**300 μm**	0.26	2.85
100	**150 μm**	0.24	2.63
200	**75 μm**	0.18	1.97
Pan		0.04	0.44



COARSE FRACTION EXAMINATION	SAMPLE #: 26725

Floor Name: Piso Don Rene

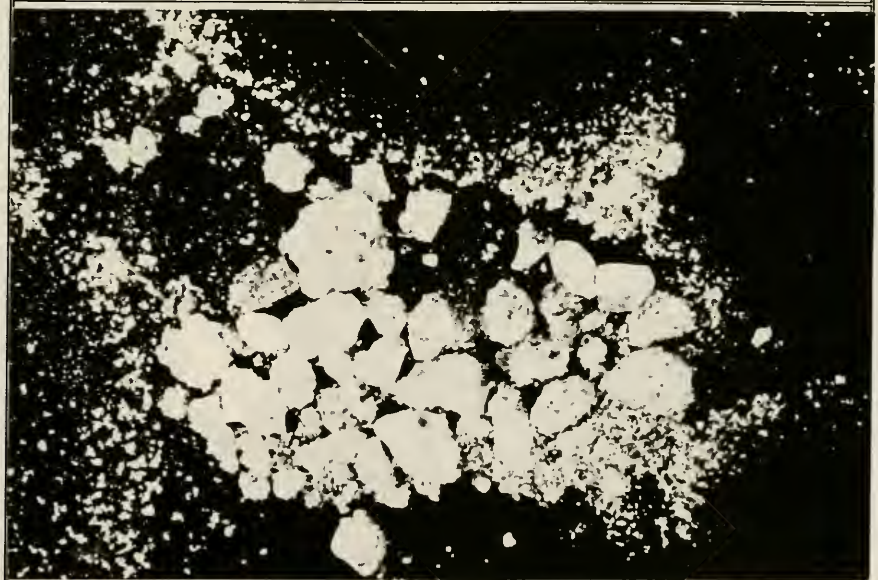
Sample Location: Rosalila, runs over top step of Azul on west side.

Division: 2	Date: A.D. 540 - 650	Magnification: 7.5x

Shapes: Subround and subangular.
Colors: Tan, brown, rust, and translucent.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	0	0
16	1.18 mm	0	0
30	600 µm	0.06	50
50	300 µm	0.02	16.67
100	150 µm	0.02	16.67
200	75 µm	0.02	16.67
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 26733-1

Floor Name: Piso Don Lorenzo

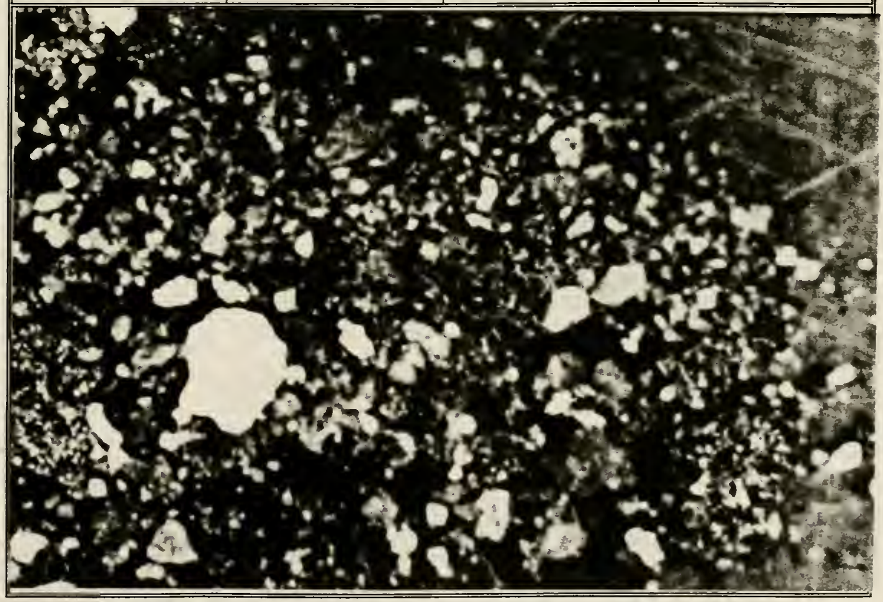
Sample Location: Rosalila, abuts modified west steps of Azul.

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 5x

Shapes: Subround and subangular.
Colors: Brown, red, white, green, gray, orange, and tan.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	0.56	4.55
16	**1.18 mm**	0.28	22.73
30	**600 μm**	2.72	22.08
50	**300 μm**	3,12	25.32
100	**150 μm**	2.04	16.56
200	**75 μm**	0.88	7.14
Pan		0.2	1.62



COARSE FRACTION EXAMINATION			SAMPLE #: 26733-2
Floor Name: Piso Don Lorencito			
Sample Location: Rosalila, abuts 1st step of original west steps of Azul.			
Division: 2	**Date:** A.D. 540 - 650		**Magnification:** 7.5x
Shapes: Subround and subangular. **Colors:** Green, red-brown, brown, tan, and white.			
SIEVE ANALYSIS			
Sieve #	**Size**	**Weight (grams)**	**% Retained**
8	**2.36 mm**	2.2	71.89
16	**1.18 mm**	0.42	13.73
30	**600 µm**	0.1	3.27
50	**300 µm**	0.12	3.92
100	**150 µm**	0.18	5.88
200	**75 µm**	0.04	1.31
Pan		0	0

COARSE FRACTION EXAMINATION	SAMPLE #: 27304

Floor Name: Piso Don Lupito

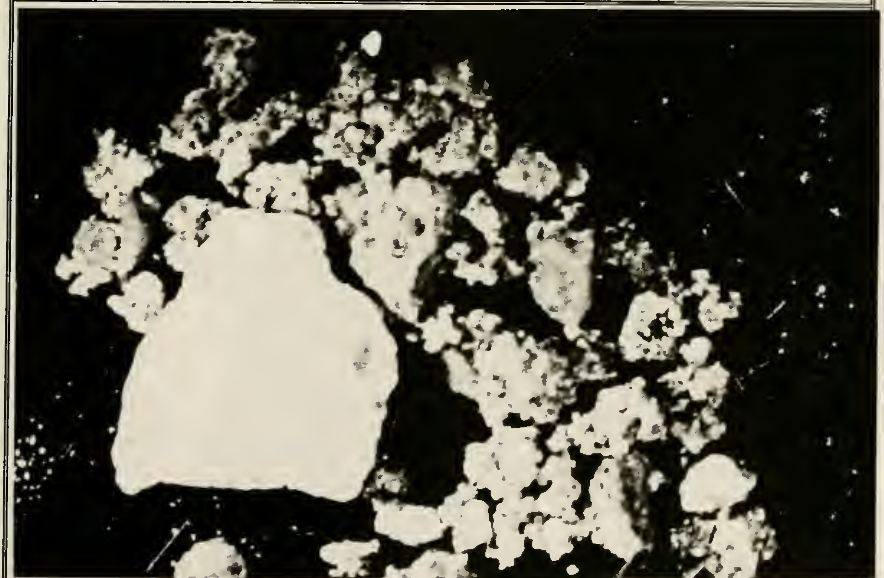
Sample Location: Rosalila, runs under Azul platform.

Division: 2	Date: A.D. 540 - 650	Magnification: 3.75x

Shapes: Subangular and subround.
Colors: Green, red-brown, brown, tan, and white.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	1.18	62.11
16	1.18 mm	0.6	31.58
30	600 μm	0.08	4.21
50	300 μm	0.04	2.10
100	150 μm	0	0
200	75 μm	0	0
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 27306

Floor Name: Piso Don Quijana

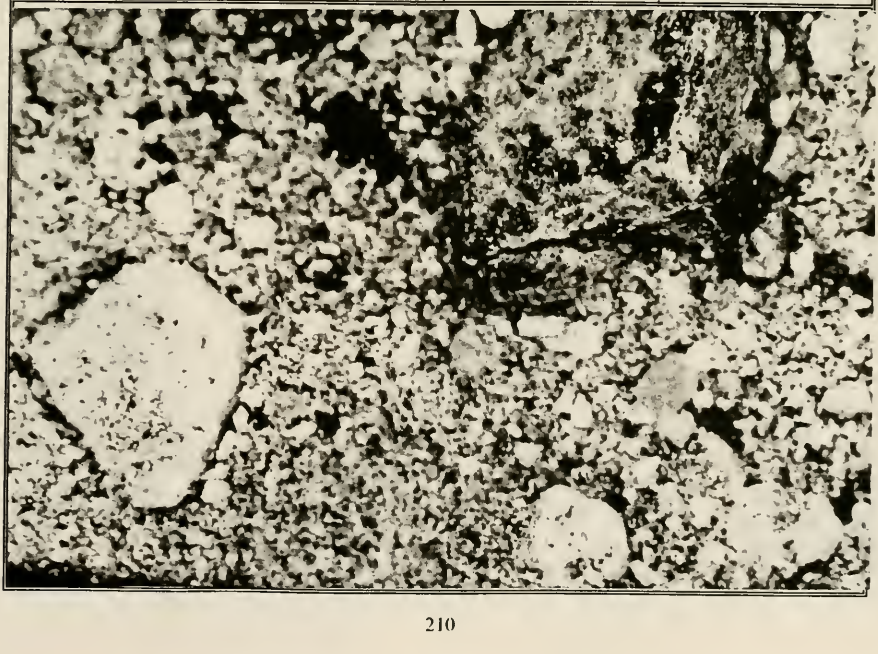
Sample Location: Rosalila, runs under Celeste.

Division: 2	Date: A.D. 540 - 650	Magnification: 5x

Shapes: Subangular and subround.
Colors: Green, brown, tan with rust, white, yellow, and gray.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	6.58	83.5
16	1.18 mm	0.3	3.81
30	600 µm	0.18	2.28
50	300 µm	0.22	2.79
100	150 µm	0.22	2.79
200	75 µm	0.2	2.54
Pan		0.18	2.28



COARSE FRACTION EXAMINATION	SAMPLE #: 28020

Floor Name: Piso Don Quizote 1

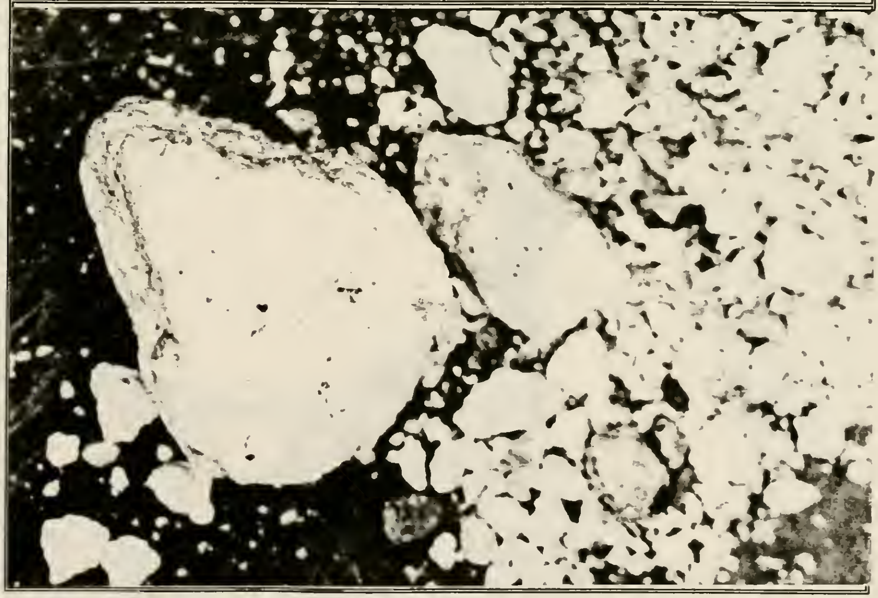
Sample Location: Rosalila, runs under original west stairs.

Division: 2	Date: A.D. 540 - 650	Magnification: 10x

Shapes: Subangular and subround.
Colors: Green, brown, gray, orange, rust, pink, and translucent white.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	2.36 mm	2.65	68
16	1.18 mm	0.07	10
30	600 µm	0.03	4
50	300 µm	0.06	8
100	150 µm	0.07	10
200	75 µm	0	0
Pan		0	0



COARSE FRACTION EXAMINATION	SAMPLE #: 28024

Floor Name: Room 5

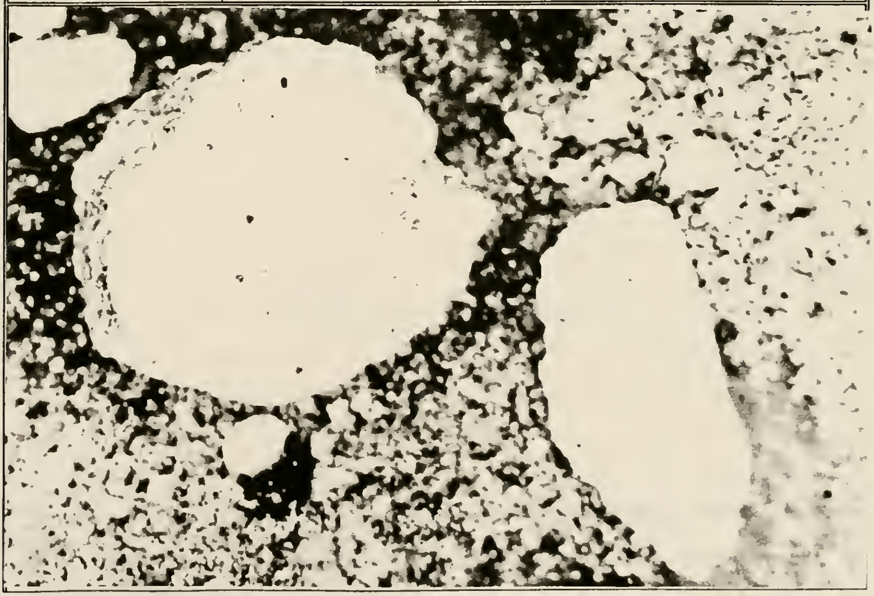
Sample Location: Rosalila, Tunnel 34

Division: 2	**Date:** A.D. 540 - 650	**Magnification:** 7.5x

Shapes: Subangular and subround.
Colors: Tan with rust, brown, green, black, tan, and white.

SIEVE ANALYSIS

Sieve #	Size	Weight (grams)	% Retained
8	**2.36 mm**	1.66	10.86
16	**1.18 mm**	2.06	13.48
30	**600 μm**	2.18	20.81
50	**300 μm**	2.42	22.38
100	**150 μm**	2.0	13.09
200	**75 μm**	1.76	18.06
Pan		0.2	1.31



4.2.9 X-Ray Diffraction

The results confirmed the findings of the visual characterization and physical testing of the subject plasters. Quartz was the dominant mineral in all of the samples submitted for analysis, followed by feldspars, probably orthoclase feldspar, and clay. Of the clay-size minerals, kaolinite, a relatively stable clay, was evident in only one of the samples (#36).[1]

The earthen plaster (#36) consisted of quartz with a lesser amount of feldspar, probably orthoclase feldspar. The clay minerals, if present at all, appeared to be kaolinite. The plaster from Division 5 (#95) consisted principally of quartz with lesser amounts of feldspar, likely orthoclase feldspar. This sample contained more quartz and less feldspar than the earthen plaster. Clay minerals may have been present but probably very little. The Division 2 sample (#59) reflected only the presence of quartz.[2]

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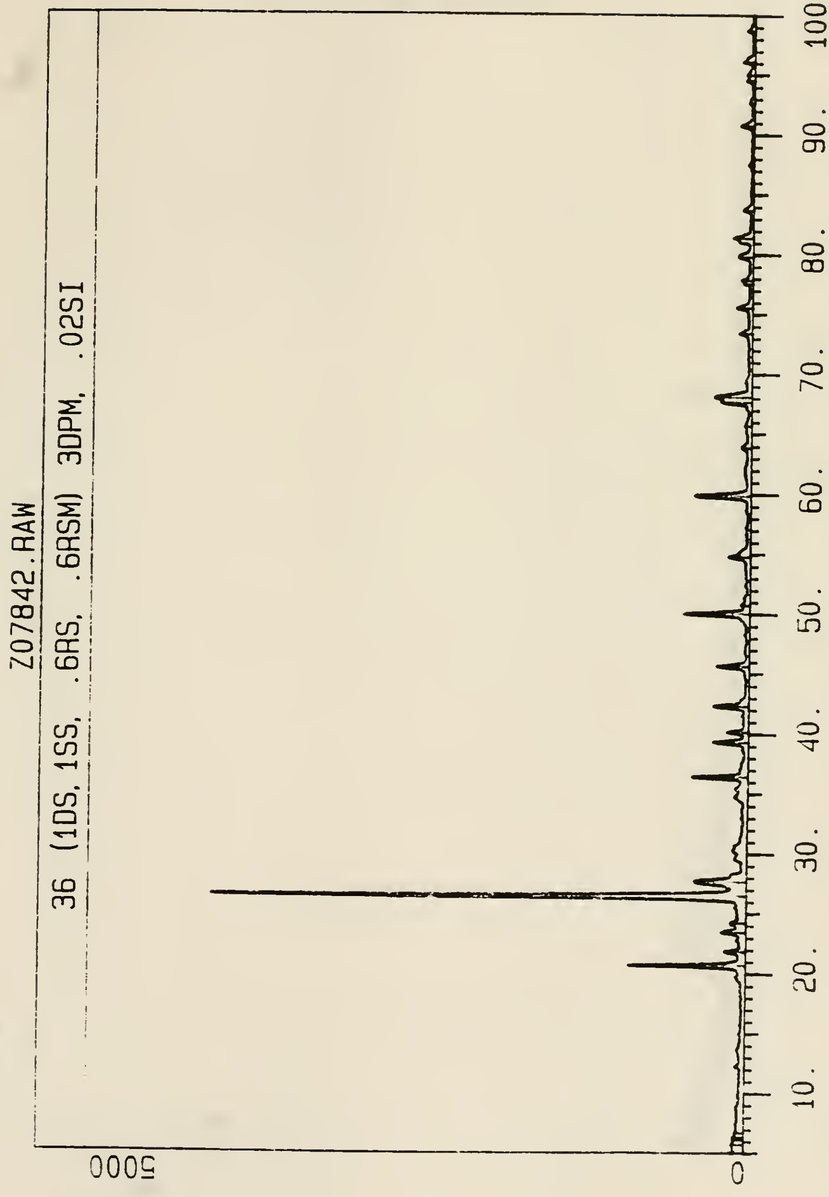
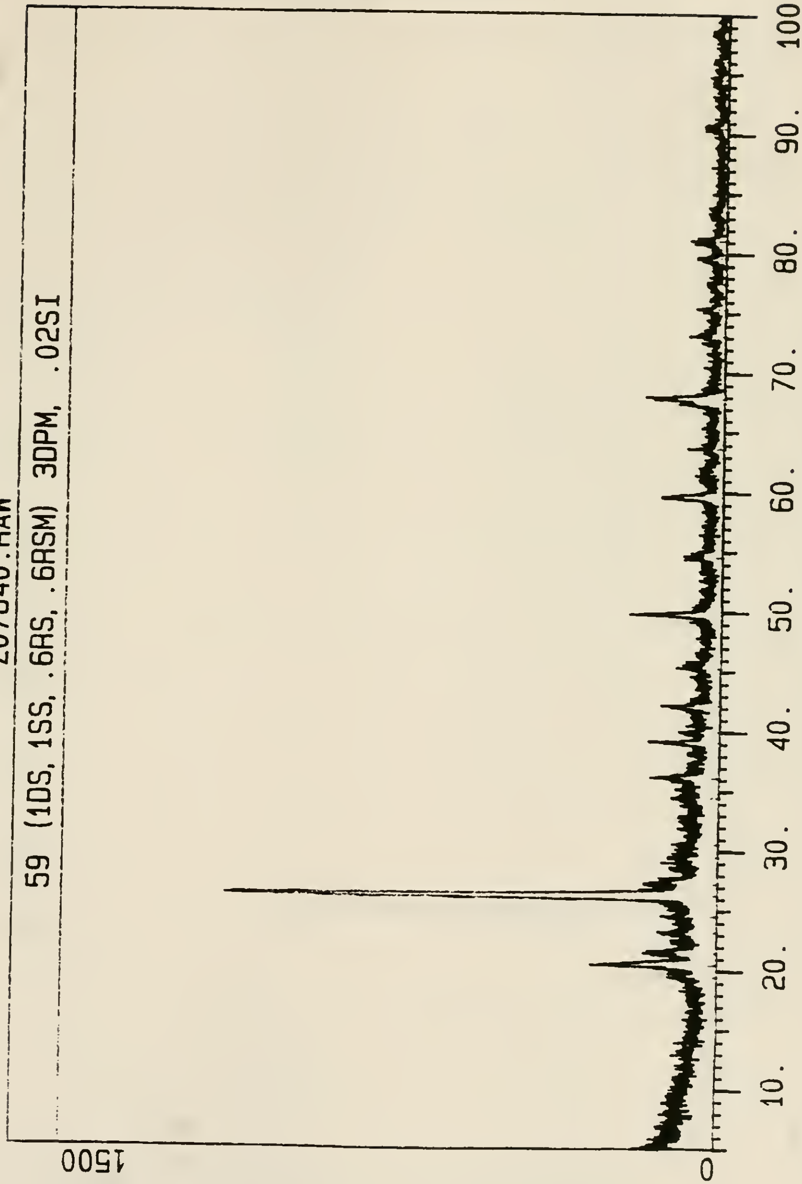
[1] The presence of clays was inconclusive in other samples due to the limited sample material available for analysis or possibly inadequate sample preparation.

[2] George Austin suggested that the reason for only one mineral quartz to be reflected may be due to inadequate sample preparation or that the presence of several minerals may produce overlapping peaks.

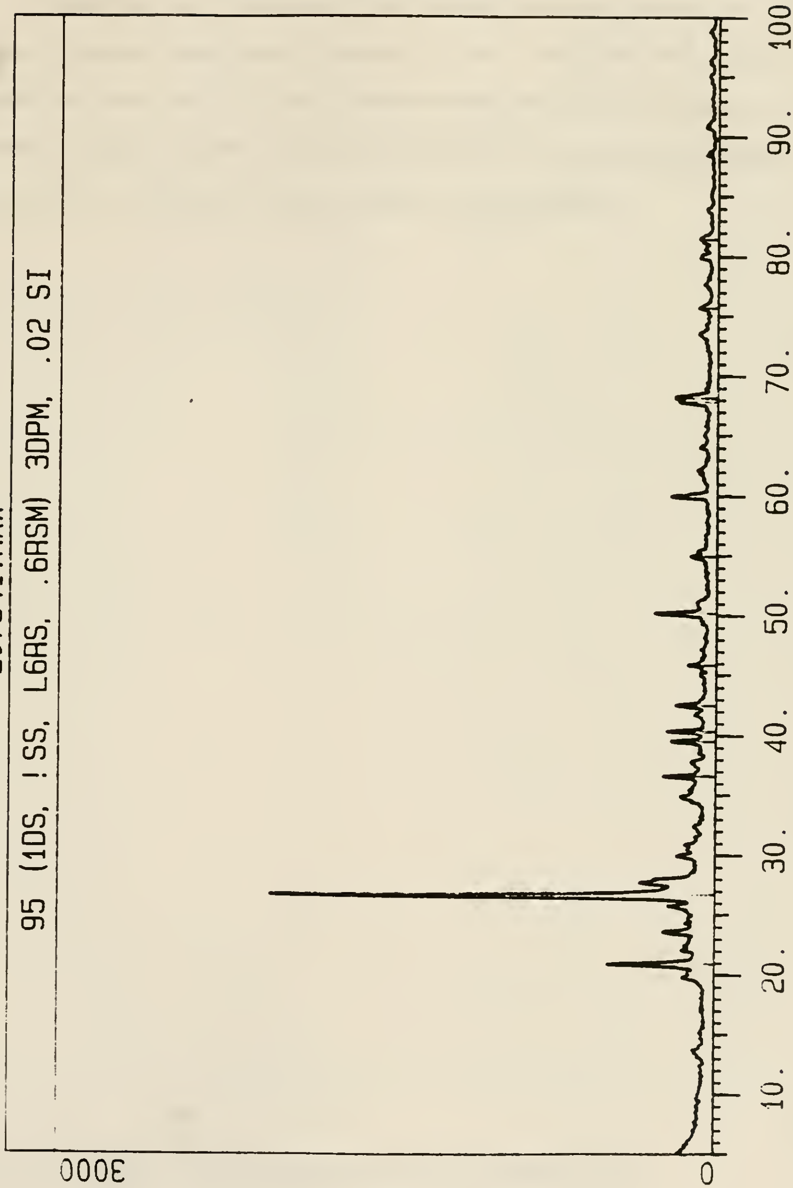
XRD ANALYSIS
SAMPLE # 36 (DIVISION 5)



XRD ANALYSIS
SAMPLE # 59 (DIVISION 2)



XRD ANALYSIS
SAMPLE # 95 (DIVISION 5)



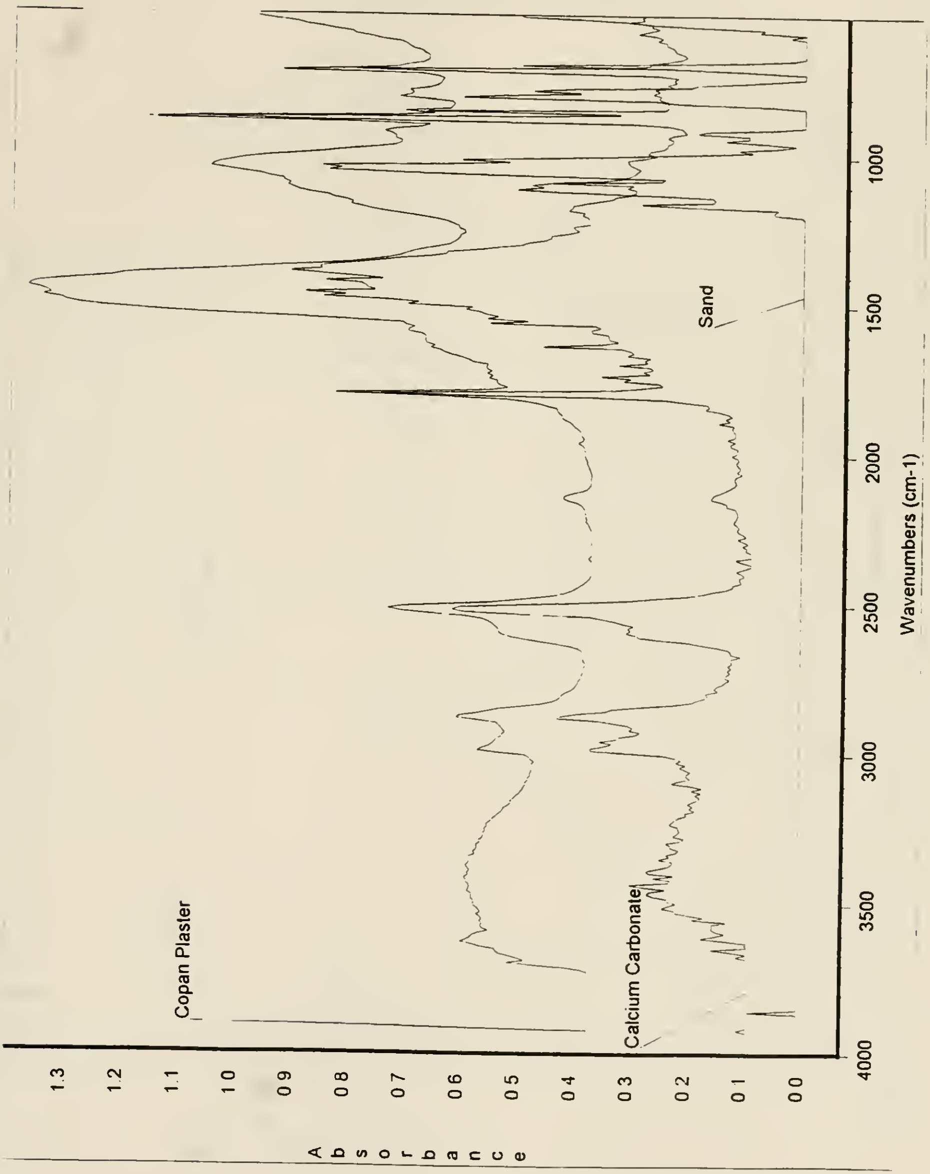
4.2.10 High Performance Liquid Chromatography

Results from the chromatographic test concluded the sample consisted entirely of inorganic materials, namely calcium carbonate and silica. The only evidence of organic materials are those found in soil which exhibited similiar peaks in the chromatogram . The detection of organic materials of this age is unlikely due to the natural decomposition of organic binders, and therefore negative results are not always reliable.[3]

[3] Paolo and Laura Mora and Paul Philippot, *Conservation of Wall Paintings*, Ibid: 73.

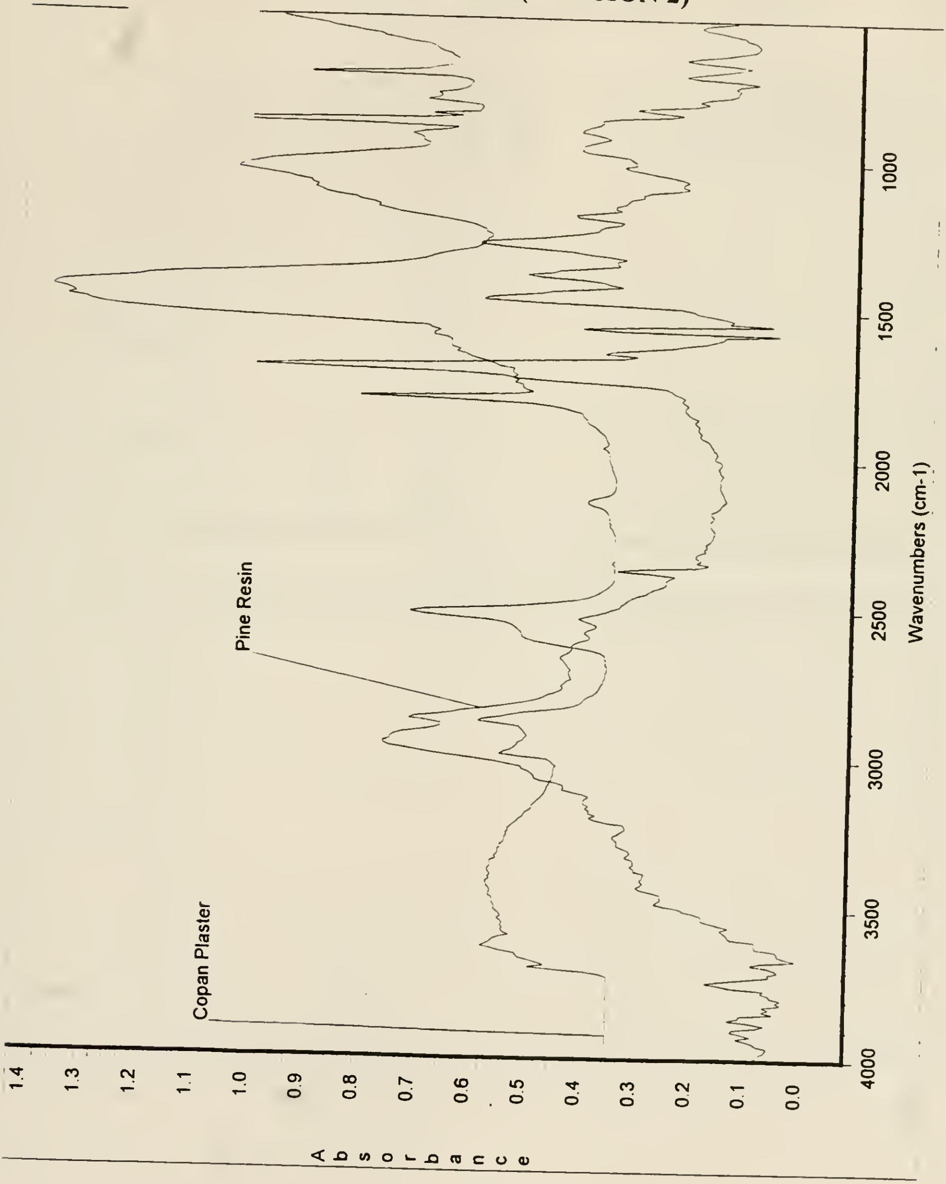
HIGH PERFORMANCE LIQUID CHROMATOGRAPHY RESULTS

SAMPLE #59 (DIVISION 2)



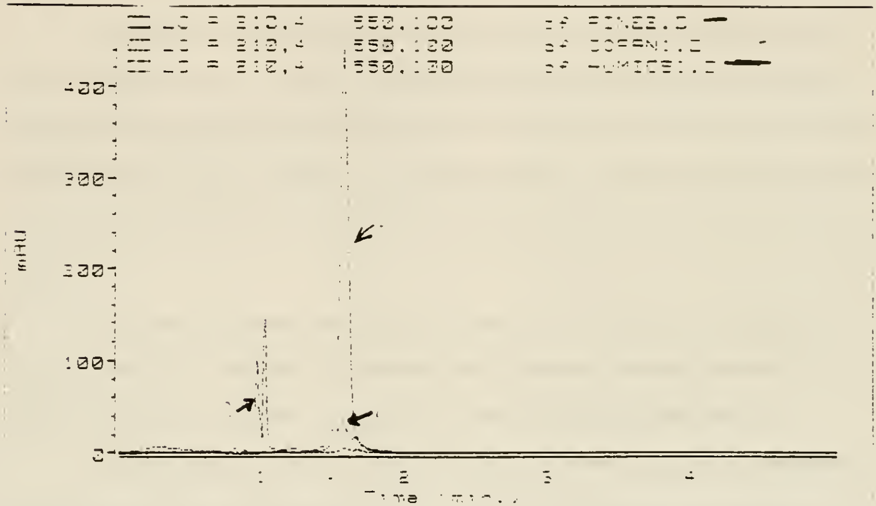
HIGH PERFORMANCE LIQUID CHROMATOGRAPHY RESULTS

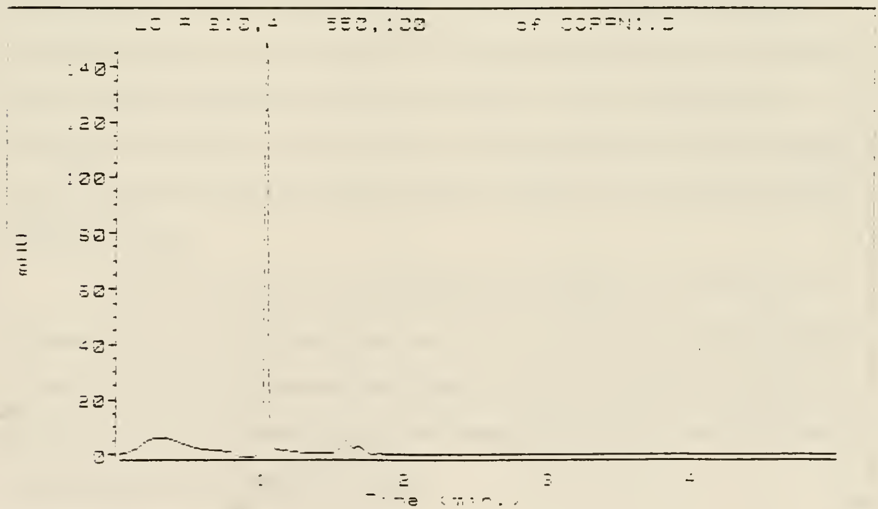
SAMPLE #59 (DIVISION 2)



HIGH PERFORMANCE LIQUID CHROMATOGRAPHY RESULTS

SAMPLE #59 (DIVISION 2)





CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

The integration of laboratory data and archaeometric studies provided insight into Maya building practices at Copan. Synchronic and diachronic variations were observed and appear to be useful indicators of technological modes and materials selection, however insufficient for attributing a plaster to a specific time period. While the variations between the earthen and lime plasters were dramatic, those among the lime plasters were more subtle.

In the interest of preserving the site's cultural assets, samples were available in limited quantities. Consequently, it remains open to conjecture whether variations in plasters samples were random, temporal, or influenced by other external factors.

Light microscopy provided the most important information about the similarities and differences between the plaster samples. Most samples viewed in cross section revealed the presence of calcite-based particles, likely representing limestone fragments which served as aggregates throughout all time spans. The use of limestone is not surprising in an area such as Copan which was not rich in limestone sources for burning lime. Aggregates derived from limestone helped economize on the amount of limestone needed for burning.

The presence of sascab was not definitively identified by optical microscopy. White-colored, sub-rounded aggregates were observed, the trait of which led Littman to confirm their inclusion in Mesoamerican plasters. However, the aggregate shapes in the Copan plasters varied, including angular and subangular particles to possibly indicate the possibility of limestone fragments as well.

Volcanic tuff and/or various types of silica sand were present in all samples to varying degrees, however irrespective of location or time period. An important difference was apparent in the aggregate shapes and sizes, displayed by the earlier use of round and coarse-sized particles replaced by a more balanced size distribution of subangular and subrounded particles. This characteristic, also evident in Magaloni's plaster investigations, demonstrated an increased awareness of the properties affected by the aggregate's grain size distribution.

The presence of certain volcanic constituents, known for imparting hydraulic qualities to mortars, was common for Old World plasters. However, this aspect was not thoroughly investigated in the study as Hyman previously found that none of the pre-Columbian plasters from the Maya region were hydraulic, despite the presence of volcanic materials. The study samples contained volcanic tuff aggregates of predominantly coarse sizes, which would likely function as inert fillers. In order to qualify as hydraulic, elements such as silicon, aluminum, and calcium must be present in specific proportions. In addition, at higher magnifications, a characteristic reaction between the elements of silica and calcium would be evident.

Unlike earthen plasters, the microcrystalline or cryptocrystalline lime matrix was generally compact and devoid of cracks, suggesting the Copan Maya had an empirical knowledge of the critical properties required for durable plasters. Finish layers were evident on some plaster samples, both from interior and exterior surfaces. Their absence on at least some other floors does not necessarily mean they were never applied. In fact, as Carelli suggested, it is probable that all floors had a finish coat. The floors had differential lengths of exposure before supplanted by subsequent floors or buildings. While some buildings were replaced quickly, others, such as Rosalila, functioned for over

one hundred years.[4] Additional sampling from other areas of the floors may help to resolve this issue.

Carbon, a by-product from lime burning, was present to a limited extent in several earthen and lime plaster samples. As Littman observed in the plasters of Tampico, the appearance of carbon considerably diminished over time, suggesting the achievement of a purer form of lime. However, it was observed in the latest time span. There is also the possibility that the decreasing amount of carbon reflects the possibility of a shortage of natural resources. Trees in limited supply for burning for example, would likely affect the production of lime and thus the plaster quality. However, both bulk sample and microscopic examination of the plasters did not exhibit substantial structural or compositional differences from preceeding divisions.

Observations of representative petrographic thin sections revealed differences by the variations in the lime matrix and the aggregate particle characteristics. The physical features of particles and their interrelationships within the material were the most significant parameters for pattern recognition.

Dramatic differences were evident between the earthen and lime plasters, in terms of both aggregate types and matrices since the former is less modified, while the latter is totally manipulated by man. The earthen plasters displayed an inconsistency in the sorting, shapes, and types of aggregates, as well as the quality of the matrices. In contrast, the lime plaster matrices were invariably fine-grained and contained similar types of quartz aggregates, albeit in varying proportions. Evidence of an increased proportion of binder to aggregates and a refinement in aggregate sorting over time, indicated an improvement in plaster quality over time. Throughout all construction sequences there were diverse,

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[4] Chris Carelli, personal correspondence, Novembe 1998.

unidentified amorphic forms present in lime matrices, possibly representing different types or strata of limestone.[5]

Gravimetric analysis is generally informative for providing relative proportions of calcium carbonate and silica. However, since the calcareous fraction constituted both the lime and partial aggregate content, it was not possible to draw definitive conclusions about their ratios. This technique however, was valuable in isolating and revealing the variety of acid-insoluble aggregates contained within the plaster matrices. Siliceous aggregates, either tuff or sand, or a combination of the two, were incorporated into the plaster mix. However, no pattern, either synchronically or diachronically, was discernible.

Determining particle size distribution provided general conclusions about the grading of individual plasters and their similarities to others. While plasters exhibited an overall improvement from the earliest division, grading was inconsistent throughout time, and confirms what Hyman found in his observations of Copan plasters. Furthermore, within a single construction sequence, several diverse particle size gradients lacking any clear relationships, were observed.

What can be ascertained about the plaster properties from the physical characteristics of the siliceous aggregates is somewhat limited, since the calcium carbonate fraction functions as an aggregate as well. However, evidence of the subtle improvement in the particle size distribution of the quartz sand fraction implied an empirical knowledge that coarse sized aggregates contributed to hardness as well as providing bulk, while the finer sized particles reduced shrinkage and cracking. This would indicate the plaster would have possessed excellent compressive strength and abrasion resistance.

On the other hand, a mixture of both subrounded and subangular aggregate particles were consistently present throughout all time spans. The presence of angular

[5] Discrepancies existed between what was observed in the cross section and thin sections of two plasters, such as the abundance and types of aggregates, suggesting that further sampling and analysis are required.

shaped aggregates would create a strong bond between the aggregates and binder, thereby enhancing strength and decreasing shrinkage. Particles with rounded surfaces would enhance workability of the plaster mix to lessen the amount of necessary water and ultimately decrease the possibility of cracking.

The presence of hydraulic clays, that might contribute to a harder, more durable lime plaster, was not definitively identified by optical microscopy or x-ray diffraction, with the possible exception of kaolinite in one earthen plaster. Further analysis employing techniques that have a greater sensitivity for detecting and quantifying hydraulic additives is advised to ascertain the relationship between the presence of clays and plaster hardness.

Organic materials, namely bark extracts, known to be used in Mesoamerican plasters, were not found in the study plasters according to the results of high performance liquid chromatography or x-ray dot mapping. As previously acknowledged, their absence may be attributed to the degradation that organic materials undergo over time, or their inclusion may simply not have been practiced at Copan. Additional testing, such as Fourier Transform infra-red spectroscopy, gas chromatography or other analytical techniques may provide further insights to any binding materials or organics added.

The issue of ritual practice involved in the construction of Mesoamerican architecture has only been touched upon in plaster studies. One unusual finding, the presence of a large inscribed aggregate in an earthen plaster (#37), hinted at the possibility of such activities. However, it rather likely confirms observations previously made by archaeologists regarding the reuse of materials for later constructions. There is significant evidence for this throughout all time periods, as coated stones and plaster lenses are often found in the fill of many buildings.[6] Interpretation of the inscription and additional sampling may shed more light on the ritualistic activities related to building construction at

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[6] Chris Carelli, personal correspondence, November 1998.

Copan. Additionally, it is possible that the inscribed aggregate originated from elsewhere in the Copan Valley where farmers occupied during the pre-Classic period.[7]

Analysis of the study plasters has yielded some insight into the production technology of the Copan plasters. First, the binding material of the plaster was composed of a calcined lime, including unburnt limestone fragments, and/or the possibility of sascab. In addition to the aggregates derived from limestone were those of the regionally abundant volcanic tuff, and silica sand which was likely obtained from the area of the Copan River. There is also substantial evidence for reused materials to be incorporated into the plaster mix. Further, a thin finish layer was applied to presumably applied to all floors, since their appearance on some would indicate the Maya were aware of the benefits of such.

Understandably, no dramatic changes over time were evident in the floor plasters using the above techniques, with the exception between the earthen and lime plasters. As utilitarian architectural units, floors do not undergo the stylistic and aesthetic transformations to the same degree of that witnessed in works of art. Once an aceptable mix was attained to fulfill its intended purpose, diachronic modifications would apt to be more subtle.

Many unanswered questions remain about the Copan floor plasters. The conclusions drawn from this study were primarily limited by the amount of sample material available for laboratory analysis. Furthermore, the employed techniques were more appropriate for examining conventional types of plasters, namely those which provide qualitative and quantitative data about the types and ratios of binder to sand content. In the case of Mesoamerican plasters, sophisticated analytical techniques are required to distinguish the limestone aggregates within lime matrices. Moreover, additional sampling would help to confirm or disprove the findings presented above to create a more statistically valid study.

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[7] Ibid.

Other significant avenues for investigation are:

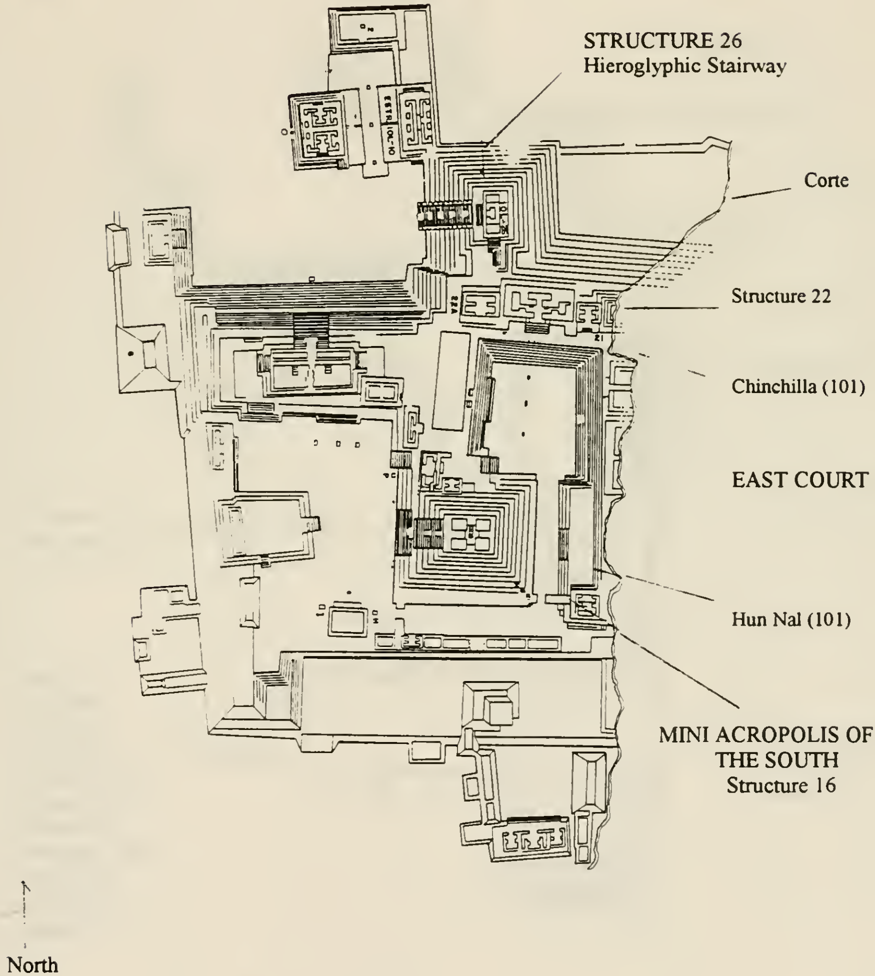
- To determine the composition of the 'inorganic' plaster finish layers. Differential thermal analysis provides information about the composition of the constituents to determine if the plasters were hydraulic.
- To determine specific locales from which the limestone was obtained. This may be achieved through x-ray florescence (conducted by a skilled technician) which can identify impurities in the limestone to help associate a plaster with a specific limestone sample.
- To compare limestone fragments with known sascab samples through scanning electron microscopy to identify the types of calcareous particles included.
- To compare the proportion of limestone aggregates used in the Copan plasters with those found in other Maya plasters to determine if there are discernible patterns, despite the varying accessibility to limestone sources.
- To correllate the changes observed in floor plasters with those of other building elements or utilitarian objects.

APPENDIX A:

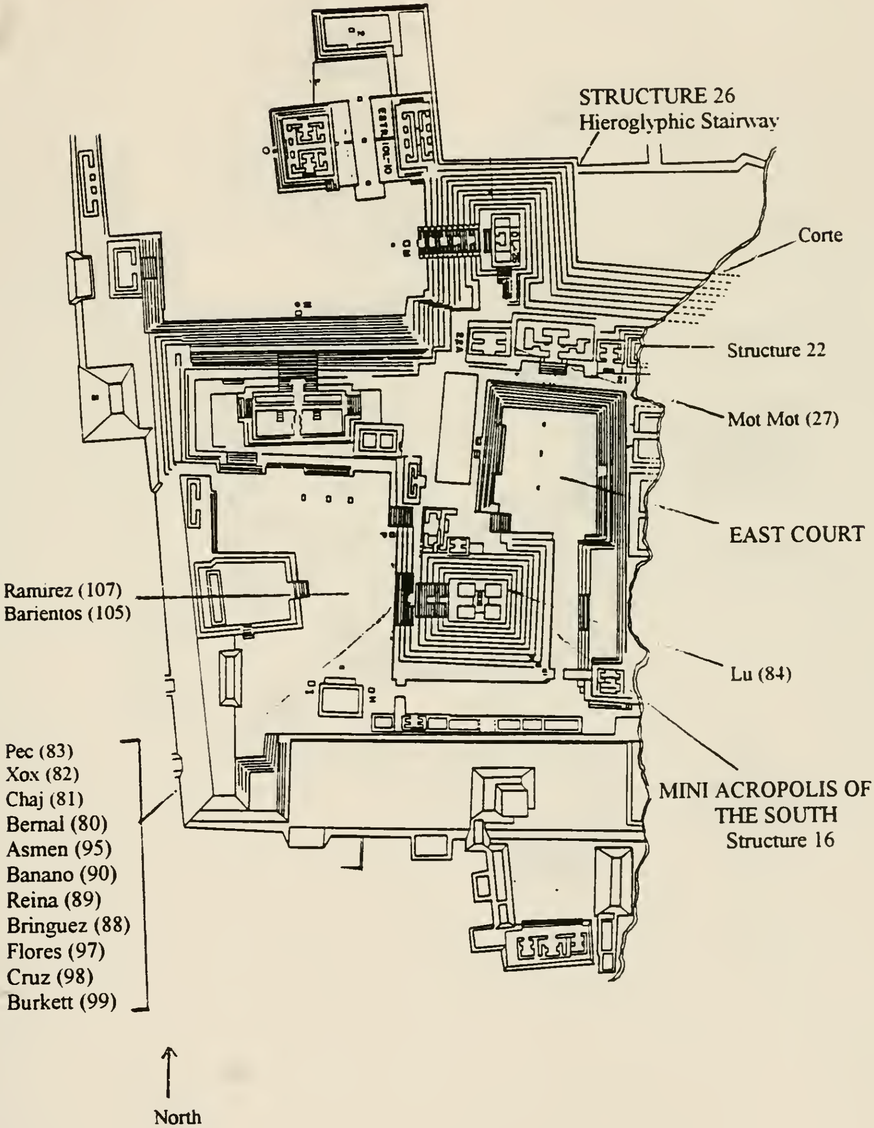
SUMMARY OF STUDY FLOORS

SUMMARY OF STUDY FLOORS				
Sample	Name	Division	Date	Location
26	Bernal	5 MAS 9	AD 440-450	Structure 26, south of Tartan
27	Mot Mot	5 MAS 7	AD 460-470	NECG, north of Tartan
28	Court 4C	4	AD 480-520	NECG, Court 4C, south of Heron
34	Gordon	4	AD 480-520	NECG, north of Toucan
35	Toucan	4	AD 480-520	NECG, Interior inside north central doorway
36	Papo	5 MAS 11	AD 420-430	NECG, below Loro
37	Chinchilla	6	BC 250-420	NECG, below Loro
38	Loro	5 MAS 7	AD 460-470	NECG, Interior, 2 meters inside south central door
40	Ganso	2	AD 540-650	NECG, Interior, north room
53	Court Flr	2	AD 540-650	NECG, south of Chachalaca, near Stuffed Olive
54	Chacha.	2	AD 540-650	NECG, Interior, south side, side of ripped out bench
58	Sharer	4	AD 480-520	NECG, south of Toucan
59	Chacha #1	2	AD 540-650	NECG, abuts east side of Chacha, last plaza floor
60	Chacha #2	2	AD 540-650	NECG, Plaza floor on east side of Chacha
61	Chacha #3	2	AD 540-650	NECG, abuts east side, 3rd surface above Indigo
63	Chacha #5	2	AD 540-650	NECG, abuts east side, 1st surface above Indigo
64	Chacha #6	2	AD 540-650	NECG, top of Indigo east side, under Chachalaca
65	Chacha #7	2	AD 540-650	NECG, abuts east side, above last plaza surface
67	Indigo	2	AD 540-650	NECG, Floor upon which Indigo rests, north side
70	Chiquito	2	AD 540-650	NECG, Floor/anden atop highest terrace, north side
71	Chiquito	2	AD 540-650	NECG, 1st floor buring 22 Chiquito, north side
72	Chiquito	2	AD 540-650	NECG, 2nd floor burying 22 Chiquito, north side
80	Bernal	5 MAS 7	AD 460-470	MAS, at juncture with Chaj
81	Chaj	5, MAS 7	AD 460-470	MAS, below Acatan, abuts Ceiba, north side
82	Xox	5 MAS 9	AD 440-450	MAS, runs under Acatan & Ceiba, side of Cedro
83	Pec	5 MAS 11	AD 420-430	MAS, runs under Caoba
84	Lu	5 MAS 10	AD 430-440	MAS, abuts Margarita, north side
85	Besh	5 MAS 10	AD 430-440	MAS, abuts Margarita, north side
88	Bringuez	5 MAS 7	AD 460-470	MAS, west of central area of west side of Tuna
89	Reina	5 MAS 7	AD 460-470	MAS, west of central area of west side of Tuna
90	Banano	5 MAS 7	AD 460-470	MAS, west of central area of Tuna, below Reina
95	Asmen	5 MAS 9	AD 440-450	MAS, west of Margarita, above Tuna
98	Cruz	5 MAS 10	AD 430-440	MAS, tops step up of Margariat platform, w. side
99	Burkett	5 MAS 10	AD 430-440	MAS, interior floor of Margarita, Xuk Pi, w. side
101	Hun Nal	6	BC 250-420	MAS, west side, top of platform
105	Barientos	5 MAS 10	AD 430-440	MAS, abuts west side of Papa steps
107	Ramirez	5 MAS 10	AD 430-440	MAS, integral with base of Papa
28020	Quixote 1	2	AD 540-650	Rosalila, runs under original west stairs
28021	Quixote 2	2	AD 540-650	Rosalila, tunnel 33, below Don Quijote 1
27306	Quijana	2	AD 540-650	Rosalila, runs under Celeste
26733-1	Lorenzo	2	AD 540-650	Rosalila, abuts modified west steps
26733-2	Lorencito	2	AD 540-650	Rosalila, abuts 1st stop of original Azul west steps
27304	Lupito	2	AD 540-650	Rosalila, runs under Azul platform
26677	Renecito	2	AD 540-650	Rosalila, west side of Rosalila
26724	Gustavo	2	AD 540-650	Rosalila, runs between Oropendola and Rosalila
26719	Simon	2	AD 540-650	Rosalila, abuts Azul base
25150	Jorge	2	AD 540-650	Rosalila, cancels Azul on west side
26701	Marcos	2	AD 540-650	Rosalila, interior floor
26725	Rene	2	AD 540-650	Rosalila, runs over top step of Azul on west side

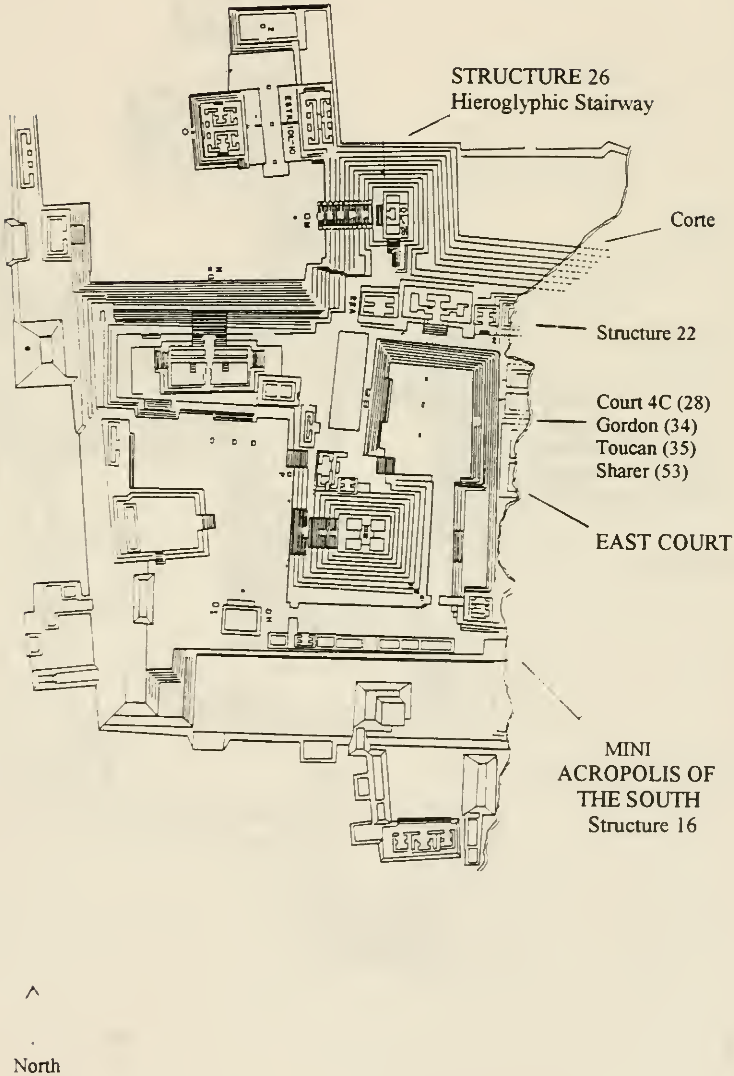
Division 6 (AD 250 - 420) Floor Locations



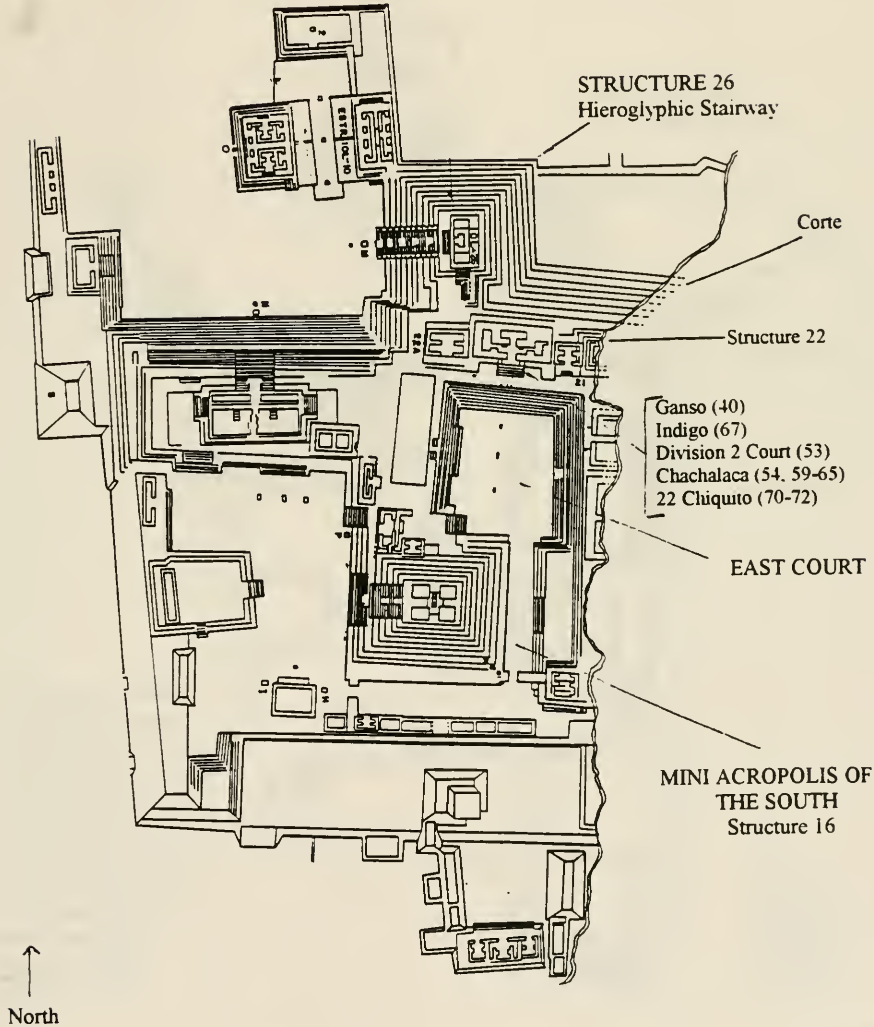
Division 5, MAS 11 – 5 (AD 420 - 480) Floor Locations



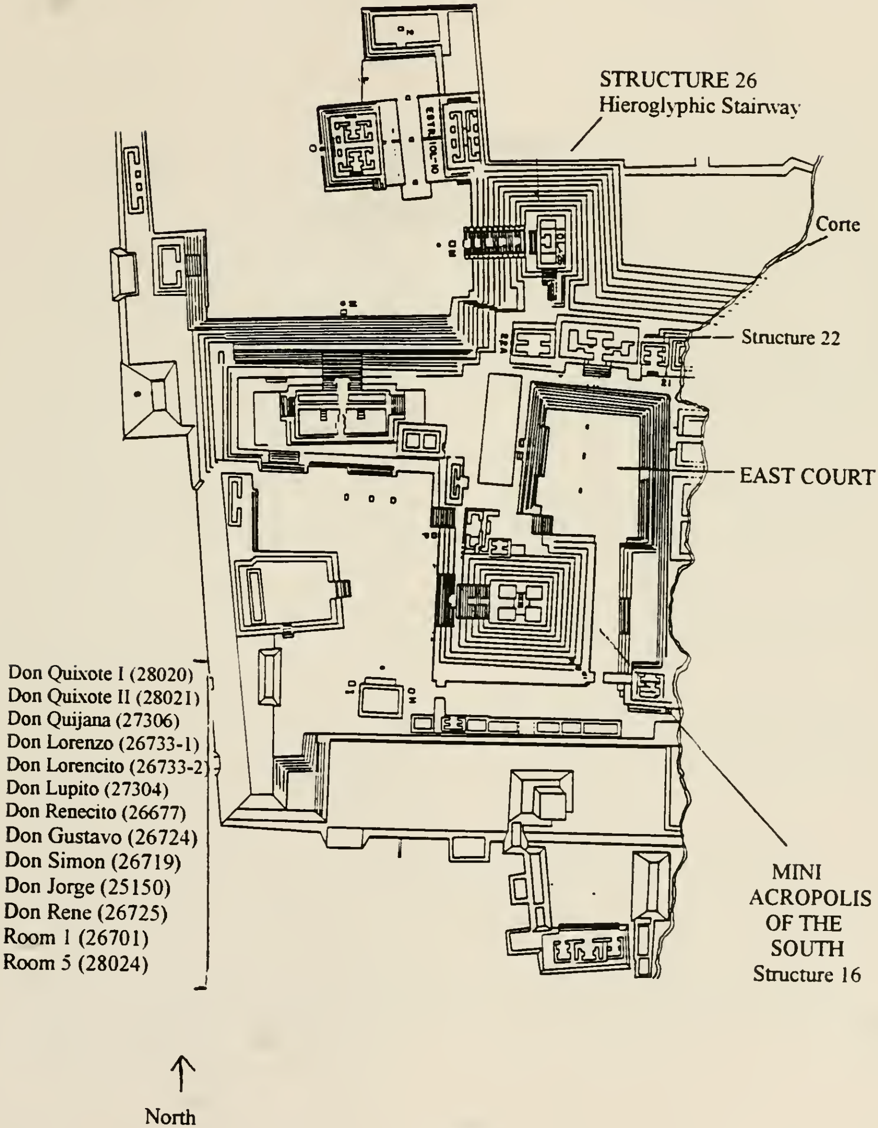
Division 4 (480 - 520) Floor Locations



Division 2 (AD 540 - 650) Floor Locations



Division 2 (AD 540 - 650) Rosalila Floor Locations



APPENDIX B

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Aggregate constitutes an inert filler material usually composed of natural sand, gravel or crushed stone.

Calcium Carbonate ($CaC0_3$)occurs naturally in nature in the form of limestone, sea shells, and corals.

Calcined Lime is a limestone that is burnt (calcined) at a temperature of 900 – 100 °C. Calcined lime is calcium oxide or quicklime.

Concrete Fill is a lean mixture of lime and aggregate filler such as sascab or sand, and possibly a coarse aggregate. It is used for structural fill material or for the construction of a monolithic mass without the brick or stone rubble. When damp, it may have the appearance of packed earth. When dry, it is generally harder than packed earth.

Lime can be made from calcium or magnesium carbonate, pure limestone or from limestone containing a proportion of clay. The amount of clay in the limestone decides whether the final product is non-hydraulic or hydraulic, that which can set under water.

Mortar is a bonding material, usually found between courses of stone or brick, as a matrix for rubble construction, and as a leveling coat on floors or the outside of the mass where it is used as a base for decorative or protective plaster. It may also contain an aggregate, such as sand, earth, ground stone, or sascab, and shell or limestone fragments.

Plaster is a flat, external coat over a monolithic mass, used as a protective medium on floors and walls or as a surface for mural painting. It is often denser than mortar and contains little or no fine aggregate.

Sascab is an inert fine, powdery aggregate or "sand" found throughout Yucatan, Belize, South Mexico, and Guatela. A naturally formed, unconsolidated limestone found in the pockets of limestone. The color ranges from white and yellow to reddish; it is chemically similar to limestone.

Stucco is a mixture of lime, water, and an aggregate which may be chemically indistinguishable from plaster. It is cast or sculptured while wet, creating a surface used solely for decorative purposes. The cementing base is lime.

Wash Coat is plaster mixed with a relatively high quantity of water applied as a thin slurry to the surface of plaster. It is extremely thin, measuring at best a few millimeters. When brushed onto wet plaster, it bonds so completely that it is often difficult to separate the two elements.

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